POINT TO POINT

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Points of view

IT HAS LONG BEEN EVIDENT that International communication networks are being called upon to handle steadily increasing traffic. Despite the establishment of new cable circuits, these networks still rely to a large extent on transmissions in the HF part of the spectrum, and heavy congestion in this frequency band limits the number of new circuits which can be established. Extra capacity can, therefore, only be obtained by getting more out of existing systems.

We have already witnessed great changes in the techniques of systems engineering in the post-war era, typified by the move to ISB and FSK operation. These changes have been accompanied by a steady improvement in the design of equipment, and a tightening of frequency tolerances in particular. We now have transmitters and receivers whose bandwidth requirements are very small, and which permit much more effective utilization of the frequency spectrum than was possible even ten years ago. Further developments, such as automatic error correction for telegraph circuits, are in the offing.

Each successive step leads to more complex equipments which, if full advantage is to be derived from them, must be operated at all times under optimum conditions. So far as is possible, the higher standards of performance will be obtained with the minimum demand on operating and maintenance staff, since improved performance at the price of continual adjustment will only be acceptable when all other lines of approach have failed.

Manufacturers are fully aware of their responsibilities in this matter, and are spending large sums of money in the development of equipment having the maximum reliability in conjunction with high performance. The implied responsibility goes further than this, in that it is part of their

task to assist the user organizations to take advantage of new techniques as they arise, and to derive from them the maximum benefit during the working life of equipment. Most manufacturers are alive to this, and with each new basic development consider the means by which they can assist their customers in getting it into operation smoothly and with the minimum of difficulty.

Much can be done by the professional Institutions and technical press, but one of the most important ways of assisting potential users of a new system is by the provision of training courses, both in the new techniques and in the operation and maintenance of specific equipment. Unless the manufacturer is prepared to assist by the provision of the fullest degree of information, by assisting the user to carry out system planning tasks, and in the ultimate by making available training courses for his engineers, then the full utilization of a new system may be seriously delayed.

Guglielmo Marconi and Communication beyond the Horizon

A SHORT HISTORICAL NOTE BY G. A. ISTED*

The paper describes experiments, carried out between 1928 and 1936 by Guglielmo Marconi, which demonstrated that transmission beyond the horizon by means of microwaves was practicable. Furthermore the influence of tropospheric mechanisms on radio-wave propagation was recognized by him at the time.

IN 1896, encouraged by Sir William Preece of the British Post Office, Guglielmo Marconi gave one of the first spectacular demonstrations of communication by means of radio waves. The frequency he used was of the order of 1 000 Mc/s. It is interesting that after over 30 years of investigation, during which period he worked successively on low, medium and high frequencies, he finally returned to his original band of frequencies in the years 1928-36.

It is also interesting to consider how different things might have been had Marconi not deviated from his original investigation of microwaves. We might by now, for example, have fully exploited the possibilities of microwave tropospheric scatter mechanisms. We might even now have been turning our attention to longer waves, where rumour would have it that communications could be established over still greater distances with less power than that used on microwaves, and we might now have

* EDITOR'S NOTE: Mr Isted's article was presented at the *Symposium on Long Distance Propagation above 30 Mc/s* held by the Institution of Electrical Engineers in London on 28th January 1958 and is reprinted with their permission. In the light of recent developments utilizing Ionospheric and Tropospheric scatter, we feel that it is not out of place at this time to reprint this article which reminds us that Guglielmo Marconi discovered the existence of these phenomena twenty-five years ago.

been theorizing on the existence of the ionosphere. That might possibly have been the more logical evolution of the art of radiocommunication. It was, however, ordained otherwise, and we are now back, in many respects, to the point at which Marconi began his work.

It cannot be said that Marconi was ever an able recorder of his own technical achievements, and it has been left mainly to others who have had intimate knowledge of his work to place them on record. His work after 1928 was no exception, and it is the pleasant task of the author, who had the privilege of being one of his personal assistants at that time, to link the experiments which Marconi carried out from that year onwards with those being carried out at the present time.

In 1928 the Presidency of the Italian Royal Academy was conferred upon Marconi. This made it necessary for him to transfer his research activities and staff from England to Italy, although his work continued to be sponsored by British interests.

It is, of course, well known now that the troposphere profoundly affects the propagation of radio waves, particularly those with frequencies within the VHF and UHF bands and beyond. The first direct reference to the influence of the troposphere on radio-wave propagation was, however, made by Marconi. This reference was made in respect of experiments, using frequencies just above 30 Mc/s, which were requested by the Italian Government. These experiments, now briefly described, were carried out between Sardinia (Golfo Aranci) and the Italian mainland (Fiumicino).

Arrays of uniform aerials, each of which probably had a gain of about 16 dB, had been erected at both the transmitting and receiving sites, which were virtually at sea level. Transmitters, capable of being modulated by a single speech channel, delivered about 1 kW of power to the aerial. Thus the system achieved an effective radiated power of the order of 40 kW. The geometrical optical range given by the combined aerial heights was not more than 34 km and the distance was 270 km — some eight times the optical range.

The experiments showed quite clearly, by beam-swinging tests, that the angle of arrival of the signal was tangential to the horizon. Meteorological conditions, whilst never causing complete failure of signals, did

cause a day-to-day and seasonal modification to the mean signal level. It was noted particularly that the signal level was some 20dB less in winter than summer.

It was this experimental evidence which prompted Marconi[1] in his address to the Italian Society for the Progress of Sciences in 1930 to say:

'From measurements effected recently it would seem that along the route between Sardinia and the Italian mainland this wave is refracted and contained within a space lying between the surface of the earth and a layer situated somewhat lower than the Heaviside layer.'

This is a fair description of the troposphere.

From the author's personal knowledge the fading characteristics on this test route were similar to those which we now observe on authentic tropospheric scatter circuits.

We must, of course, bear in mind that during these 30 Mc/s experiments sporadic-E ionization could have been present. It is also recorded that round-the-world echoes were observed which indicated the probability also of F_2-layer propagation; both these factors may possibly have influenced the results. Nevertheless, the continuous presence of the signal at all times makes it certain that tropospheric mechanisms must have been the dominant influence.

It was at the conclusion of these tests that Marconi turned his attention again to the investigation of the behaviour of microwaves. This time he was not alone in this field. Very early in the 1930's Uda[2] in Japan succeeded in communicating between Sendai and Otakamori, a distance of 30 km, on frequencies of the order of 600 Mc/s; Pistor[3] in Germany had made valuable contributions to the microwave art; Clavier and Gallant[4] established a 2-way communication link across the English Channel between St Inglevert and Lympne on a frequency of the order of 1 500 Mc/s. Marconi himself very soon succeeded in demonstrating communications over distances of the order of 35 km on 600 Mc/s so convincingly that the Vatican Authorities requested him to provide a similar equipment for communication between the Vatican and the summer residence of His Holiness the Pope at Castel Gandolfo. This installation, the first microwave telephone in the world, was put into regular service[5] in February 1933. Marconi, however, had no real interest in

these short-distance line-of-sight transmissions. His ambition was to break down the barriers which dared to impose limitations on the propagation of the radio waves he had made his life's study. With this in his mind he set himself the task of removing the barriers which, at that time, seemed destined for the first time to prevent him from communicating to distances beyond the horizon.

All workers in the microwave field in the early 1930's used the humblest of apparatus. This fact explains the absence of the precise measurements to which we have become accustomed in the past decade or so. There were literally no radio-frequency devices available for the measurement of power, signal intensity, attenuation or indeed frequency itself. A brief description of the apparatus used by Marconi may therefore serve to demonstrate the difficulties under which he, and indeed other contemporary workers, carried out their pioneering work. It may also serve to enhance their early technical achievements.

The backbone of the electronic apparatus was, without doubt, the so-called electron oscillator.

Barkhausen and Kurz discovered in 1919 that, when they applied a negative potential to the anode of a triode valve and a high positive potential to the grid, very-high-frequency oscillations were set up; whether

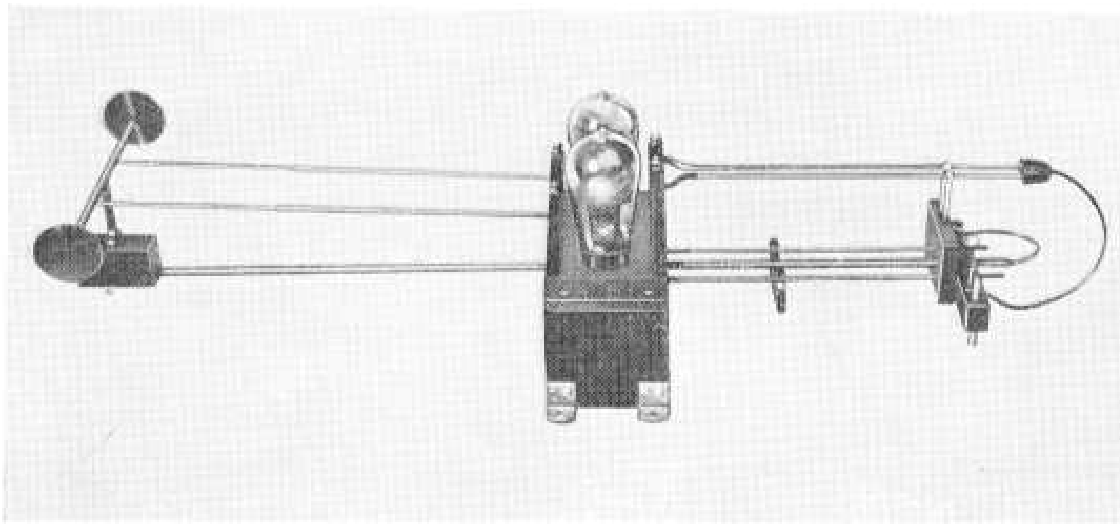

Fig.1. An early type of 600 Mc/s oscillator unit, using one pair of push-pull valves, connected in the Barkhausen-Kurz manner. The dipole is capacitance-loaded by circular end discs

this was discovered by accident or design is not recorded. It was further found that the frequency generated in this manner, usually higher than 300 Mc/s, was largely dependent upon the applied potentials. Gill and Morrell, in 1922, showed how the Barkhausen-Kurz electron oscillator could be coupled to an oscillatory circuit.

Not every valve would produce the Barkhausen-Kurz continuous-wave oscillations, and when one was found which did, its life often terminated after a few minutes' operation, usually owing to the fact that the grid had melted.

One of the first requirements at this stage was a reliable valve. Marconi developed one during his first year's work which had a life of about 40 hours, and a power output of the order of 5 watts at a frequency of 600 Mc/s. A transmitting unit was developed consisting of two valves operating in push-pull with associated tuning lecher wires in the grid, anode and filament circuits; the dipole aerial was directly coupled to the grid circuit (see Fig.1). Four of these units—eight valves in all—were used in parallel, all being kept in phase by an interlinking lecher-wire system; a formidable arrangement even by modern standards!

All four dipoles of this arrangement were situated in a broadside manner at the focus of a five-unit fishbone parabolic reflector. A conservative estimate of the effective radiated power of this particular arrangement is 4 kW.

Frequency modulation of the transmitter was obtained by the simple expedient of modulating the anode negative potential.

The receiver consisted of a pair of push-pull valves connected in the Barkhausen-Kurz manner and used in conjunction with a paraboloid aerial. A more portable version of this receiver, incorporating a fishbone parabolic reflector and dipole aerial, is shown in Fig.2. The radio-frequency 'detector' was followed by a 2-stage audio-frequency amplifier—only four valves in all. The secret of the success of this remarkable little receiver undoubtedly lay in the fact that, by patient and cunning manipulation of the grid and anode potentials, and the grid, anode, and filament tuning lecher wires, the receiver could be coaxed to the state where it just failed to oscillate on the required frequency; this state was

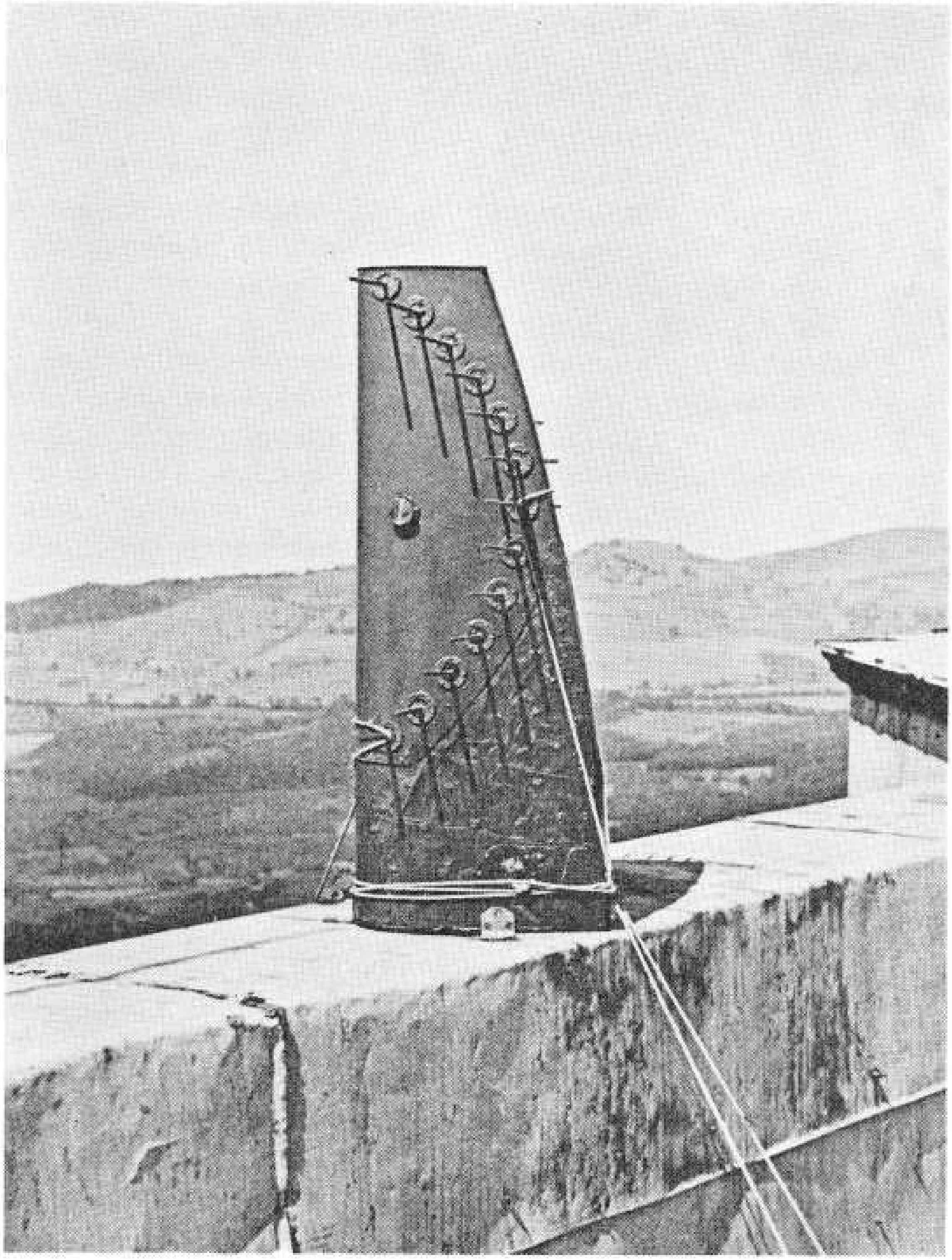

Fig.2. The portable 600 Mc/s receiver, incorporating a fishbone parabolic aerial, used in many of Marconi's experiments

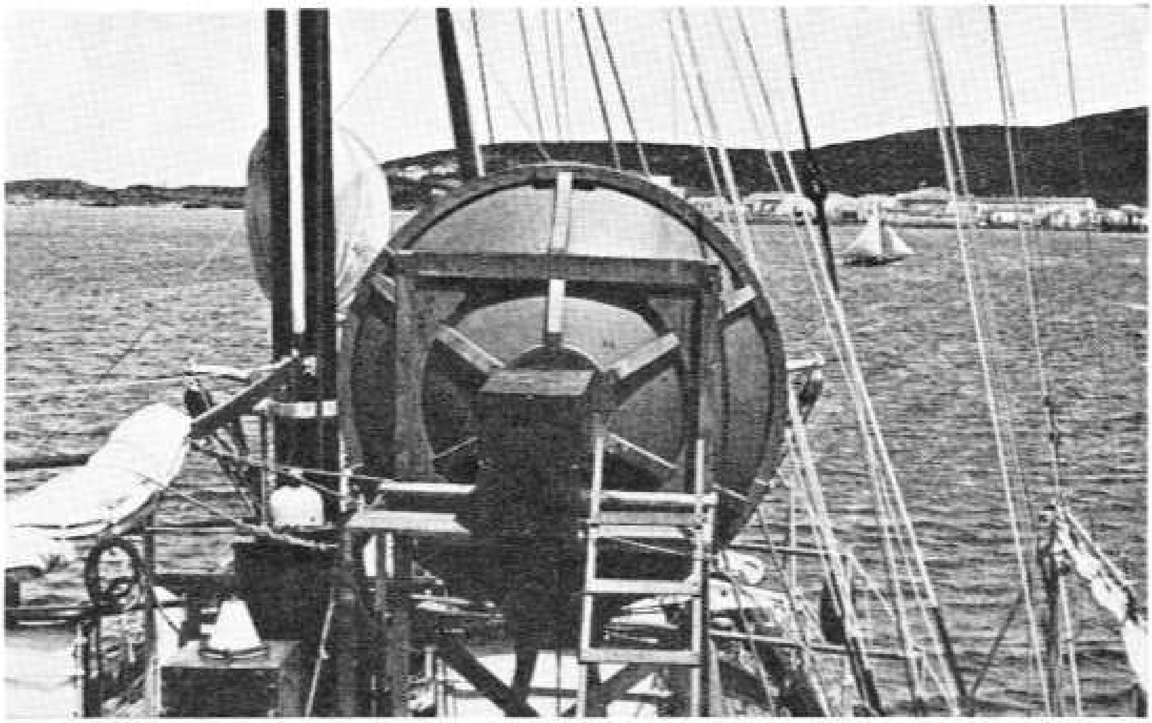

Fig.3. The 600 Mc/s receiver, with large paraboloid aerial mounted at the aft end of the 'Elettra's' boat deck, used for long-distance experiments

superbly sensitive as users of orthodox regenerative receivers will recall with some nostalgia.

It was with this apparatus, crude by modern standards, that Marconi set out in 1932 supremely confident that he would yet again confound the physicists and mathematicians of the day who were of the opinion that communication beyond the horizon was an impossibility by means of microwaves, or as they were then called, quasi-optical waves.

Marconi was particularly fortunate in having at his disposal the steam yacht *Elettra*, now alas, through the vicissitudes of war, lying at the bottom of the Adriatic. With this vessel he was able to study the behaviour of radio waves from their source up to distances at which signals were no longer audible.

The first experiments[6] were carried out with the transmitter installed on the roof of the Hotel Miramare at Santa Margherita, on the Italian Riviera; the receiver was located in the stern of the *Elettra* (see Fig.3). This arrangement gave an optical range of about 27 km.

Observations made while the *Elettra* steamed away from the transmitter showed repeatedly that signals could be received up to about three or four times the optical range. The behaviour of the signal repeated from one day to the next; the salient features being that up to the horizon fading was shallow and slow, but beyond the horizon fading became deep and fairly rapid.

Tests were carried out a month or two later from Rocca di Papa (Rome), from a height of 700 m, with the transmitting aerial array directed across the sea towards Sardinia. The receiver remained in the same position at the stern of the *Elettra*. The optical range under these new conditions was about 90 km.

Repeated tests again showed that microwaves could be reliably propagated to distances exceeding the optical range by two to three times. The behaviour of the signals conformed closely to those received from the lower transmitting terminal at Santa Margherita. During these experiments signals were received up to distances of 240 km. Continuing this series of experiments Marconi conducted microwave tests from two elevated terminals—one at Rocca di Papa and the other at Capo Figari (Sardinia) at a height of 340 m—separated by a distance of 270 km with an optical range over sea of 150 km.

In these tests it was established by beam swinging that the angle of arrival of the signal was tangential to the horizon, and in the direction of the transmitter. Furthermore, for the duration of the tests, the signals were always present, albeit with notable fading.

Marconi was now well aware of the effects of meteorological conditions upon radio communications as is shown by Vanni[7]. He was of the opinion that the reception of radio waves at distances beyond the horizon could be attributed to the effects of the lower atmosphere. He was also convinced that some stratification would eventually be identified which would enable microwaves to be usefully propagated to distances of the order of 400-500 km. With this in mind the supporting structures of both transmitting and receiving parabolic aerials were modified in a manner to allow the main aerial lobes to be elevated by substantial amounts. With this facility, tests were carried out in the autumn of 1932 between Rocca di Papa and the *Elettra* anchored in the harbour at

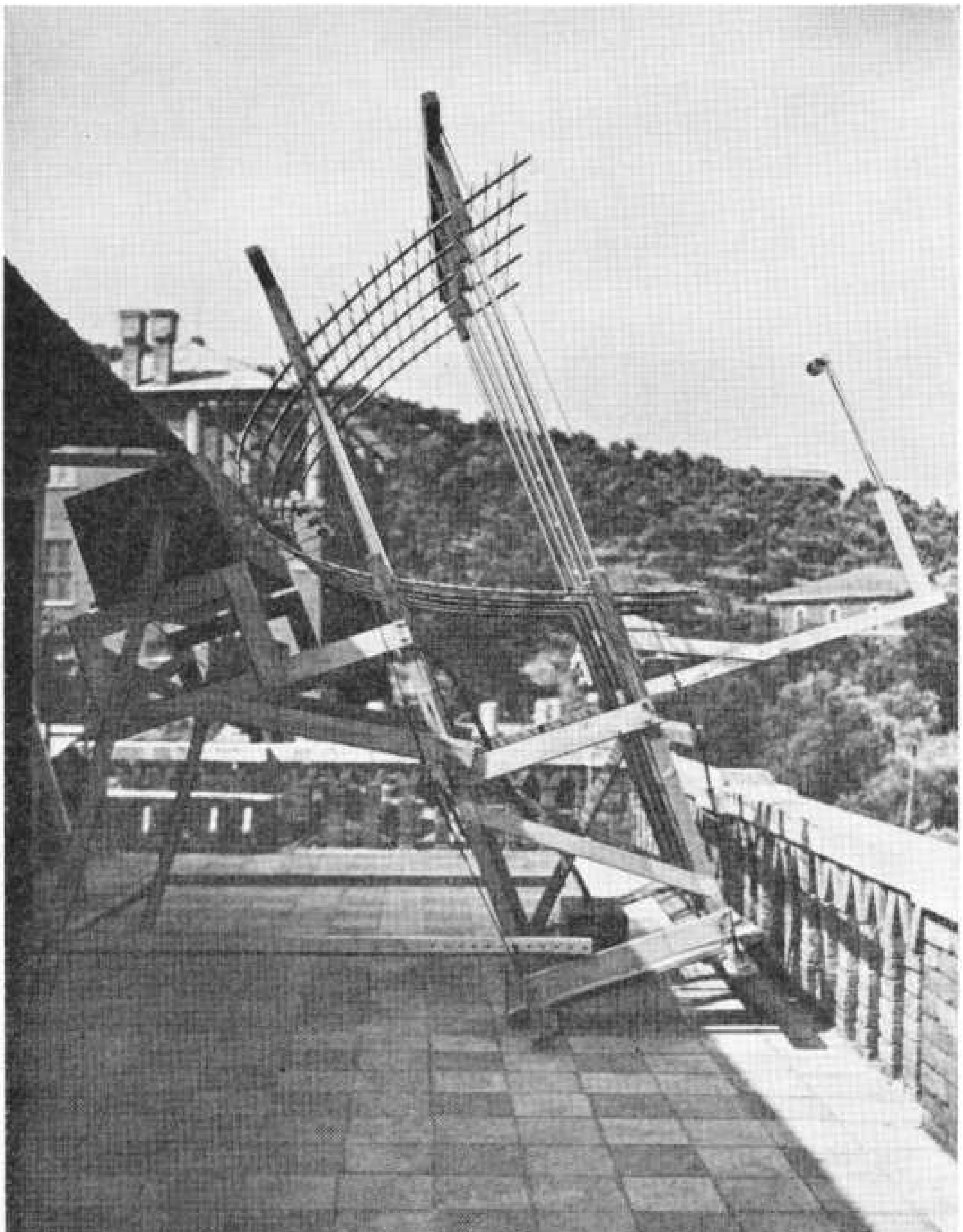

Fig.4. The five-unit fishbone parabolic aerial tilted at a substantial vertical angle during the Rocca di Papa—Venice long-distance test

Venice, a distance of 400 km. The optical range in these particular experiments, because of intervening hills, was restricted to 70 km. Reception tests were made while the transmitting and receiving parabolic aerials were synchronously tilted upwards by successive small angles of elevation. Fig.4 shows the transmitting aerial arranged for a substantial vertical angle.

The experiments failed—probably because the distance was too ambitious considering the relatively low power radiated. On the other hand the author, who was responsible for the instrumentation of the test, has never been able to satisfy his conscience that the receiver and transmitter were ever brought into tune with one another. It was, in fact, the first time that an attempt was made to receive signals over a great distance without first being able to commence the experiment in the vicinity of the transmitter, where the tuning procedure was relatively easy and certain.

After the failure of the Rocca di Papa – Venice experiments great efforts were made to increase the power of the transmitter and the general stability and efficiency of the apparatus. The resulting improvement was so effective that Marconi decided to carry out further propagation tests with the *Elettra* in August 1933.

The new transmitter was installed again at Santa Margherita. The *Elettra*, with the receiving aerial installed at the stern, then steamed in a south-westerly direction along the Italian coast. Signals were monitored continuously during the voyage, and, apart from the occasions when navigational requirements made it impossible to maintain the receiving parabolic aerial directed towards the transmitter, signals were received throughout the voyage as far as the harbour of Santa Stefano. The total distance covered was 258 km, i.e. nine times the optical distance. This distance was achieved in spite of the fact that high hills intervened at two points along the route.

Carroll[8] has recently pointed out that this particular experiment indicated, without doubt, that Marconi had discovered experimentally the existence of microwave propagation beyond the horizon which could not be explained by diffraction and refraction. This was the identical point of view expressed by Marconi[9] himself in the account he gave of

11 Via Condotti,
Rome, 17th August, 1933.

H.A. White, Esq.,
Marconi House, Strand,
London, W.C.2.

Dear Mr. White,

Enclosed herein, I beg to forward, for your information, copy of a Note I have presented on the 14th instant to the Physics and Mathematics Section of the Royal Academy of Italy, on my recent tests of radiotelegraphic and radiotelephonic communication by means of micro-waves.

From perusal of this Note you will see that the Transmitter being placed at Santa Margherita Ligure at a height of only 38 metres, strong, fully commercial speech was received on board the "Elettra" at a distance of 150 kilometres, while Morse signals were still detected on the Yacht at Porto Santo Stefano over a distance of 258 km., notwithstanding intervening land with high hills. The fallacy of range limitation attributed to the socalled quasi-optical waves remains thus conclusively proved, the optical distance having been exceeded by almost nine times.

Further improvements in the apparatus are likely again to revolutionise radio communications.

The tests will be resumed in about ten days, when the transmitting apparatus will be installed at Rocca di Papa, near Rome. Full report will be forwarded on the conclusion of these tests.

Yours sincerely,

G Marconi

Fig.5. Reproduction of one of Marconi's letters at the conclusion of the Santa Margherita-Santa Stefano tests

the experiment to the Physics and Mathematical Section of the Royal Academy of Italy on 14th August 1933.

Sir Ambrose Fleming[10] has emphasized that Marconi's predominant interest was not in purely scientific knowledge *per se*, but in its practical application for useful purposes. So it was typical of Marconi that, having proved to his own satisfaction that microwaves could be utilized for all manner of purposes, he set about developing and demonstrating some of the practical applications. Amongst these applications were specific navigational aids[11], which imposed a heavy demand upon the services of the *Elettra*, and precluded her further participation in propagation experiments. Had it not been for this, the propagation tests would undoubtedly have continued and our present knowledge of tropospheric mechanisms might well have been much more advanced.

Considered in retrospect there is surely every reason to believe that, by his repeated demonstrations that signals were receivable beyond the horizon, even up to eight or nine times the optical range on both 30 and 600 Mc/s, Marconi utilized the same tropospheric mechanisms which we ourselves are only now actively investigating. It is interesting to note furthermore that we are slowly coming to the same conclusions that Marconi reached in one of his letters, reproduced in Fig.5, written a quarter of a century ago.

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G. A. ISTED, born 1903 in Terling, Essex. Educated at King Edward VI Grammar School, Chelmsford. He joined the Marconi Company in 1923 and was attached successively to various production departments and helped in the installation of the historic high-power long wave broadcast transmitter '5XX' at Daventry. In 1926 he was transferred to Marchese Marconi's private research laboratory at Marconi House in London. In 1929 he went to Italy to assist Marconi in his investigation of microwave propagation there. While in Italy he was responsible for the installation of the first microwave telephone apparatus at the Vatican. He returned to Chelmsford in 1936 and joined the staff of Mr T. L. Eckersley and was engaged again on radio-wave propagation. Shortly after the outbreak of World War II he was seconded to the Air Ministry with the 'Eckersley Group' and when the wartime Inter Services Ionosphere Bureau was formed at the Marconi Research Laboratories he was responsible for the observation and interception side of its activities. Since the war he has been engaged entirely on radio-wave propagation studies which in recent years has included ionospheric and tropospheric investigations in particular. He is now Chief of the Field Studies Group of the Research Radio-wave Propagation Section.

Printed Circuits and High Quality Amplifiers

DURING THE 1930's Dr Eisler, working under the sponsorship of a large English printing firm, explored the possibility of applying the experience and methods of the printing industry to the production of electronic wiring patterns. His early experiments with metal powders and inks printed directly on to insulating boards convinced him that the only suitable type of conductor was one made from metal foil. Logically he proceeded to the idea of an insulator with its entire surface covered with foil, and by using inks which were resistant to etching chemicals, he removed the unwanted areas, leaving the desired conductor pattern.

By the early 1940's Dr Eisler had patented most of the ideas which are the basis of today's processes. All of his development was, however, carried out on a laboratory scale. His concepts were not immediately acceptable to the electronics industry and he found the steps between the laboratory and production line were long and required considerable capital investment.

During the period of development towards a production process the chief advantage of printing a circuit was considered to be the facility for auto-assembly with its consequent reduction of costs on quantity production. The most important prerequisite for this auto-assembly system was a foil-coated insulated board material which had to be inexpensive and capable of withstanding soldering temperatures, drilling and punching strains. At the same time, the insulation had to be of a high standard, with

low moisture absorption. Laminated plastics were the obvious choice for the insulating material, and copper, silver or aluminium for conductor foil. Silver was considered to be too expensive and aluminium was difficult to solder, and so work was concentrated on a phenolic laminated board to which a copper foil was securely bonded. The first results of this development became available in the U.S.A in 1949 and immediately following this, several organizations in Great Britain started developing production processes.

The results of this work soon showed that an etching process could be evolved permitting very accurate reproduction of inductances, and close control of the circuit stray capacitances to a degree unobtainable with the usual circuit wiring processes. Thus, whereas the general application of printed wiring was considered to confer the advantage of production cost reduction, an application was also revealed by which a standard of special excellence was available.

At the time that this development was taking place, work on broad band microwave links had reached the stage at which intermediate frequency amplifiers were required, having extremely accurately controlled gain and phase characteristics. The required transmission responses had been obtained in the laboratory, and it was possible that they could be reproduced in the factory, but the quantity of specialized test equipment and the technical skill required to obtain these responses were obviously impracticable for routine maintenance in working systems. An alternative approach was therefore necessary and resulted firstly in the development of circuits unaffected by valve variations, ageing and climatic changes. This enabled precise component values to be assigned, thus permitting the use of printed circuit techniques, and has given rise to a new technology.

A major problem encountered with this type of printed circuit was that of making connections from the foil to external points, without introducing mechanical strains. Any strain of this kind could cause the foil to lift from the insulating board and eventually to fracture. All interconnecting leads carrying low frequency currents are therefore made via special eyelets which rivet the foil at these points as well as providing electrical termination. For RF interconnection points, a special co-axial

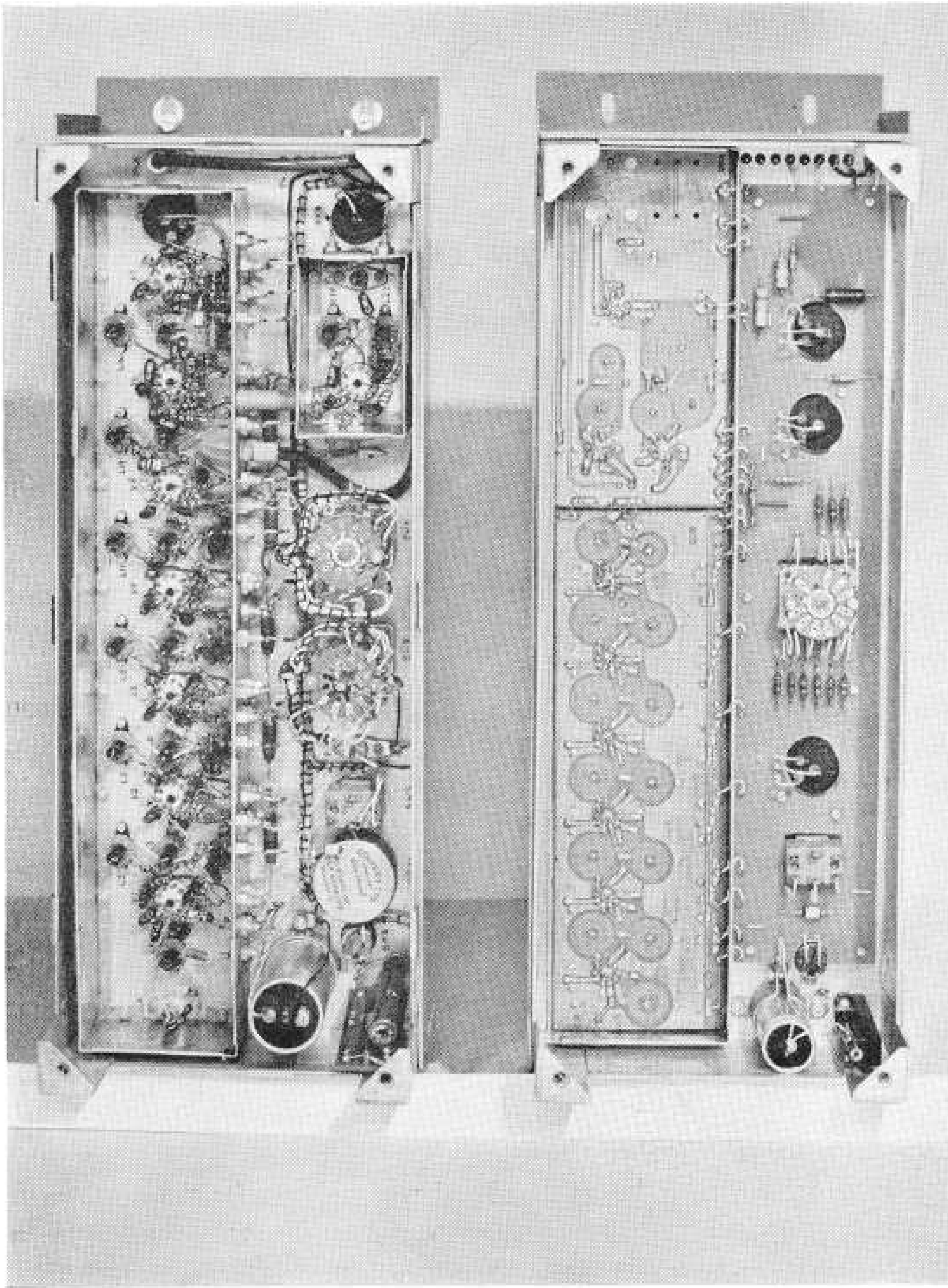


Fig.1. Alternative designs – Conventional and Printed Circuit

connector has been designed which, as well as removing all strain from the foil, also provides a mechanical connection between the board and metal chassis on which it is mounted. Since it is inconvenient to place the RF connectors directly at the feed points, a printed strip line of accurately controlled impedance has been utilized.

One other component of considerable importance, which if not carefully designed could cause damage to the copper foil, was the valve holder (since at the present stage of valve development it was considered desirable to use plug-in types of valves). A special valve holder has been designed which has a PTFE insulating body which fits snugly to the laminated board. Since the thermal conductivity and capacity of the board is poor, it is necessary to conduct the heat of the valves away from the printed circuit. This is accomplished by mounting the boards parallel to a metal chassis and relying on the valve screening cans to conduct the valve heat to it.

The complete printed circuit includes no tuning adjustment of any kind and therefore all components which can influence the transmission responses of the circuits must be of the highest stability. This also implies that the leads of these components must always be set to the same electrical value and to control this a manufacturing procedure has been developed to ensure that these leads are accurately bent and mounted.

Finally, the effects of climatic variation must be removed. This is accomplished by coating both the components and the printed circuit with a material which does not affect the electrical characteristics of the board or the overall performance.

The use of a printed circuit leads to a new concept of maintenance. The replacement of a faulty component could easily cause mechanical damage to the copper foil, and since the complete circuit has an enveloping coat to protect it against humidity, faulty components cannot, in any case, be replaced without re-sealing. The equipment is therefore so designed that each printed circuit board is low in cost and easily replaced by a wireman or instrument maker without the services of a technician. All components of finite life, such as switches, potentiometers, high current resistors or electrolytic capacitors, are mounted on the main chassis in an accessible manner.

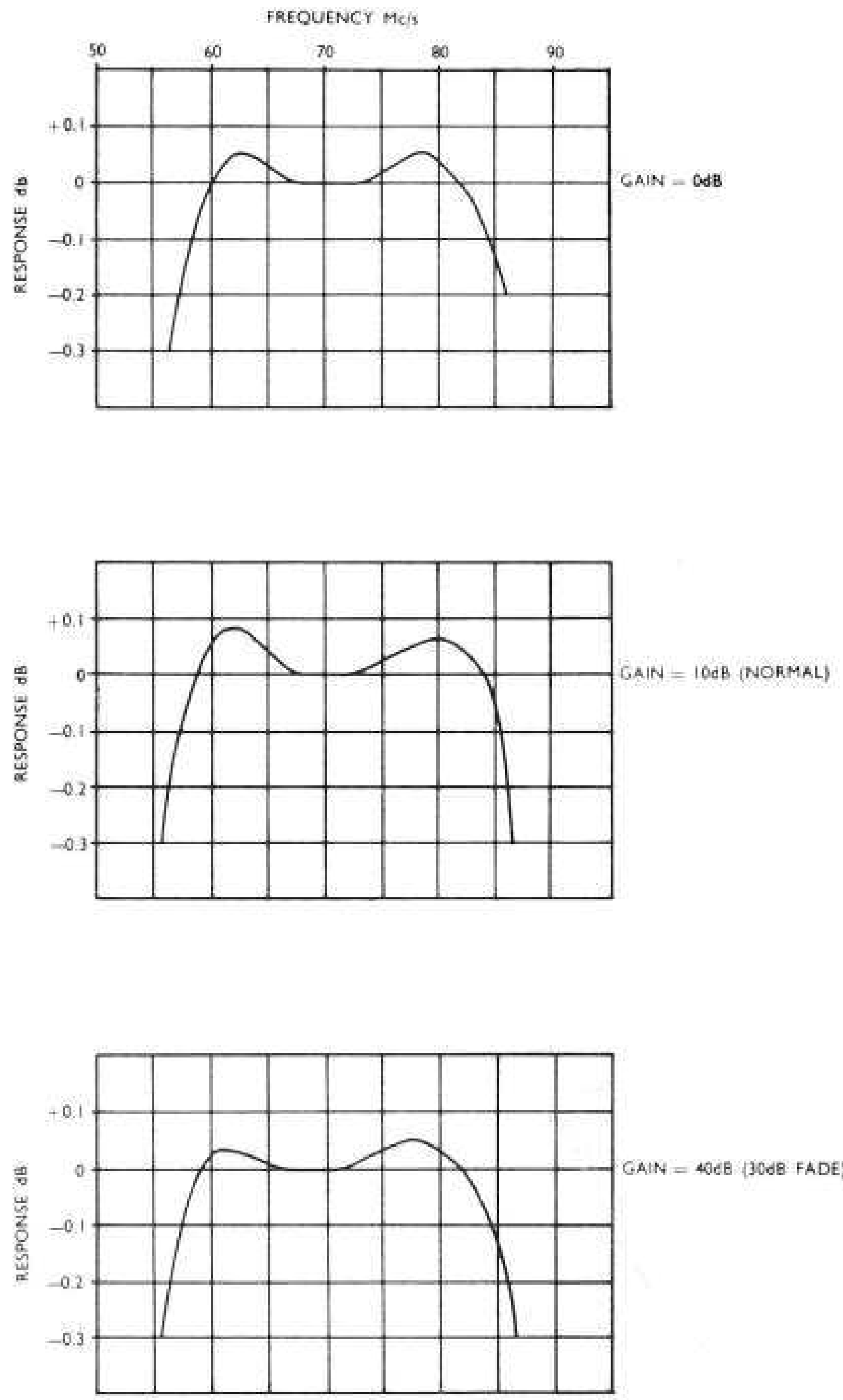


Fig.2. Transmission v. frequency response showing variation due to gain change

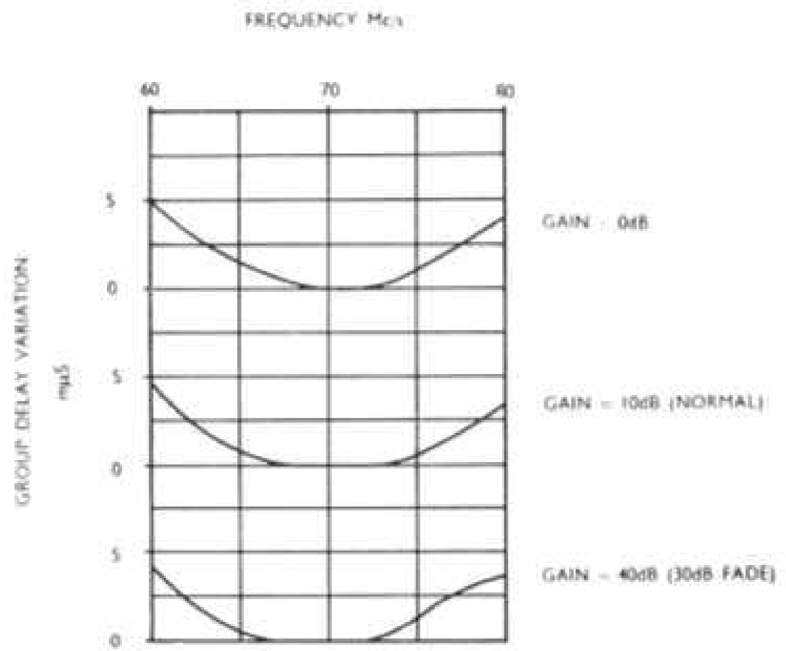


Fig.3. Group delay variation v. frequency showing variation due to gain change

Fig.1 shows an IF amplifier using printed circuits and one of conventional design which fulfils the same requirement. The printed circuit amplifier includes an additional stage to the conventional type and its performance is much improved as shown in Table 1. These amplifiers are both designed to be preceded by low noise pre-amplifiers but whilst the transmission response and group delay of the printed type is adequate for a 600 channel or colour television FM signal, the conventional design is suitable for only 240 channels or black and white television. A graph of transmission charactistics of the printed design is illustrated in Fig.2 and the group delay variations in Fig.3. These characteristics are unaffected by valve ageing or tolerances. The essential characteristics of the two amplifiers are as follows:

Table 1

COMPARATIVE PERFORMANCE TABLE

Parameter	*Conventional Design*	*Printed Circuit Design*
Input:		
Impedance	75 Ω	75 Ω
Return Loss (65-75 Mc/s)	20 dB	26 dB
,, ,, (60-80 Mc/s)	—	20 dB
Level ref 220 mV	−30 to +10 dB	−30 to +10 dB
Output:		
Impedance	75 Ω	75 Ω
Return Loss (65-75 Mc/s)	—	26 dB
,, ,, (60-80 Mc/s)	—	20 dB
Level ref 700 mV	−1 to +0·5 dB	±1 dB
Frequency Response:		
±0·1 dB points	65-75 Mc/s	58-83 Mc/s
−0·25 dB points	63-77 Mc/s	56·5-87 Mc/s
Bandwidth (limit group delay)	65-75 Mc/s	60-80 Mc/s
(Linear variation $<1 m\mu$ Sec.) (Quadratic variation $<6 m\mu$ Sec.)		

Production experience has proved that this performance is adequately maintained in practice. The production testing required is of the simplest nature and testing time is reduced by over 50%.

Automatic Error Correction on HF Telegraph Circuits

P. R. KELLER, B.Sc, A.M.I.E.E

Automatic error correcting equipment has already proved its ability to increase the efficiency with which telegraph traffic is transmitted over HF radio circuits. The number of circuits incorporating automatic error correction is as yet relatively small, but can be expected to increase considerably in the near future. This article covers the principles of error correction, based on the Van Duuren system recommended by the C.C.I.T for international circuits, and also outlines the design of equipment.

1 INTRODUCTION

THE LIABILITY of HF telegraph systems to transmission errors due to fading and interference has always been a limitation in communications networks, but is inherent in the medium. With manually handled messages this has been largely mitigated by visual inspection and subsequent repetition of errors. This procedure reduces the traffic capacity of a network but was accepted when comparatively long time delays were regarded as tolerable.

The increasing development of Telex services on an international basis requires the establishment of circuits of guaranteed transmission accuracy. To obtain the required performance on HF telegraph circuits, automatic examination and, if necessary, the immediate repetition of an incoming transmission is called for.

Numerous solutions are possible, and considerable work has already been done in developing a system of this kind in conjunction with a protected code, initially with electro-mechanical equipment but latterly using electronic designs, by Dr Van Duuren of the Netherlands P.T.T.

This work has led to a recommendation by the C.C.I.T on the adoption of this system for international circuits. Using the Van Duuren principles, much work has also been carried out in the United Kingdom, notably by the G.P.O Research Establishment at Dollis Hill and also by the Telegraph Development Unit of Cable and Wireless Limited. The present article deals with equipment meeting the C.C.I.T recommendations, permitting the establishment of substantially error-free circuits.

An error correcting terminal requires certain ancillaries in addition to the error-correction equipment. The additional units which are required to permit full integration with automatic internal networks are also discussed.

2 TELEGRAPH CODES

Radio telegraph circuits normally employ 2-condition codes; examples in common use are morse, double current cable code, 5-unit (start-stop or synchronous), and 7-unit synchronous.

Inland telegraph circuits use the 5-unit start-stop code almost exclusively. In this code each character is represented by five elements, mark or space, and there are therefore 32 different permutations available. Fig. 1 shows the allocation of characters in the international telegraph alphabet. Figure shift and letter shift are used to extend the number of characters which can be transmitted. The elements of a character are normally transmitted sequentially on one wire, and to maintain synchronism between the transmitting and receiving equipments a nominal speed of transmission is employed (normally 50 bauds, or elements per second). The 5-unit character is preceded by a start (spacing) element and followed by stop (mark) polarity for approximately $1-1\frac{1}{2}$ elements.

The efficiency of 5-unit code (or of any code with a constant number of elements per character) can be increased by omitting the start and stop elements, which convey no information, and adopting other means of maintaining synchronism between the transmitter and receiver. Synchronous working results in a higher speed in words per minute for a given telegraph speed.

Unless 5-unit code is used also for the radio circuit, more or less elaborate conversion equipment must be provided at the terminals, and

skilled operators may be required. The 5-unit code is, however, particularly vulnerable to the interference normally experienced on HF radio circuits, since it possesses negligible redundancy (i.e. all possible 5-unit permutations, except signal No. 32, represent a character). As a result, a mutilated character (e.g. a mark lost or gained) cannot be detected and will cause an incorrect character to be printed. This is particularly serious if an erroneous Figure Shift is received while receiving lower case characters, as the subsequent copy will be printed in the wrong (upper) case.

3 PROTECTED CODES

If the number of elements representing a character is such that there are more possible permutations than characters, the code possesses redundancy. The mutilation of a character in transmission may then give a permutation which does not correspond to any true character, and is therefore unacceptable. The form of the code must be chosen so that the possibility of a mutilation giving an incorrect but acceptable character is minimized.

As an example, the simplest protected code is one in which a character is represented by six elements, the first five of which are as in the 5-unit code, and the sixth is made mark or space to make the total number of marks always an odd number, 1, 3 or 5. Errors due to changes of an odd number of elements can then be detected automatically while undetectable errors result from a change of two or four elements.

3.1 THE 7-ELEMENT 3-MARK CODE

The most important protected code used on radio circuits is that in which a character is represented by seven elements, of which three are always mark and four are space. A simple mark count checks the acceptability of each received character. Undetectable errors only occur when the change of a marking element to space is accompanied by the change of a spacing element to mark in the same 7-element group.

In this code there are 35 permutations available, of which 32 are allocated to represent the characters of the 5-unit international telegraph alphabet, and two can be allocated to the supervisory conditions, continuous mark and continuous space.

Combination Number	*Letter Case*	*Figures Case*	*Start*	*Code Elements*					*Stop*
1	A	—	○	●	●	○	○	○	●
2	B	?	○	●	○	○	●	●	●
3	C	:	○	○	●	●	●	○	●
4	D	Who are you?	○	●	○	○	●	○	●
5	E	3	○	●	○	○	○	○	●
6	F	* (%)	○	●	○	●	●	○	●
7	G	* (@)	○	○	●	○	●	●	●
8	H	* (£)	○	○	○	●	○	●	●
9	I	8	○	○	●	●	○	○	●
10	J	Bell	○	●	●	○	●	○	●
11	K	(	○	●	●	●	●	○	●
12	L	)	○	○	●	○	○	●	●
13	M	.	○	○	○	●	●	●	●
14	N	,	○	○	○	●	●	○	●
15	O	9	○	○	○	○	●	●	●
16	P	0	○	○	●	●	○	●	●
17	Q	1	○	●	●	●	○	●	●
18	R	4	○	○	●	○	●	○	●
19	S	'	○	●	○	●	○	○	●
20	T	5	○	○	○	○	○	●	●
21	U	7	○	●	●	●	○	○	●
22	V	=	○	○	●	●	●	●	●
23	W	2	○	●	●	○	○	●	●
24	X	/	○	●	○	●	●	●	●
25	Y	6	○	●	○	●	○	●	●
26	Z	+	○	●	○	○	○	●	●
27	Carriage Return		○	○	○	○	●	○	●
28	Line Feed		○	○	●	○	○	○	●
29	Letter Shift		○	●	●	●	●	●	●
30	Figure Shift		○	●	●	○	●	●	●
31	Space		○	○	○	●	○	○	●
32			○	○	○	○	○	○	●

● Mark ○ Space * Optional

Fig. 1. 5-unit start-stop code. International telegraph alphabet No. 2

4 CODE CONVERSION

At the radio transmitting and receiving terminals it is necessary to translate between the codes used on the radio and inland circuits. Manual methods have been used which involve printing the characters received in one code and making perforated tape in the other code for retransmission. It is more convenient, and operating costs are reduced, if code translation is effected by automatic converters. Mechanical, electromechanical and fully electronic automatic converters have been devised.

We are concerned here with converters translating between the 5-unit teleprinter code and the 7-unit 3-mark code. The allocation of the 35 permutations can be made in a great number of ways and the design of the converter is simplified if this is done in such a way that there is a logical relationship to the 5-unit code. The first practical automatic code converter, devised by Dr Van Duuren, used electro-mechanical relays, and the code logic devised for this unit is not well suited to an elegant design of an electronic converter. Other codes have since been proposed (e.g. Higgitt No. 2) which permit the design of a relatively simple electronic converter but, owing to the well-established use of the original code, and the evident need for an international standard, the C.C.I.T have recommended that the Van Duuren code be preferred.

An alternative form of translating equipment, which does not require a logical relationship between the codes, comprises a first part, which converts a 5-wire input to a 32-wire output, and a second part, which converts a 35-wire input to a 7-wire output. By appropriate connections between the 32-wire output of the first part and the 35-wire input to the second, any 7-element 3-mark code can be constructed. Such converters use more components than a logical translator, but are more flexible.

5 AUTOMATIC ERROR CORRECTING SYSTEMS

When a 7-unit code containing a constant number of mark elements is used, a means exists for the automatic repetition of a faulty character.

On the detection of an error in the incoming 7-element character (wrong mark count) the transmission of the 5-unit output to the printer is stopped, and a special RQ combination (the 35th permutation of the code) requesting a repetition is inserted in the return circuit.

TERMINAL 1	TRANSMIT	B	C	D	E	F	**RQ**	**C**	**D**	**E**	**F**	G	H
	RECEIVE	P	Q	R	S	**RQ**	P	Q	R	S	T	U	V
	PRINT	P	Q	R	S						T	U	V

TERMINAL 2	TRANSMIT	Q	R	S	**RQ**	**P**	**Q**	**R**	**S**	T	U	V	W
	RECEIVE	A	B	★	D	E	F	**RQ**	C	D	E	F	G
	PRINT	A	B						C	D	E	F	G

Fig.2. The automatic repetition cycle

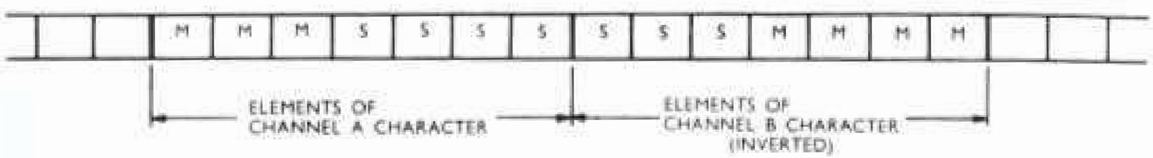
Whenever a character is transmitted over the system it is also stored for a period not less than the loop propagation time of the system. The receipt of the RQ signal at the originating terminal automatically stops the intake of new characters for transmission, and causes the re-transmission of the required character together with the other characters in the store. Normal traffic and printing is resumed when the repetition is received without error. (A further error in the repetition originates another repetition cycle, and so on, until the character is received correctly.) Since the erroneous character might have been the RQ signal in the other direction of the circuit, it is arranged that the request for a repetition is itself followed by a repetition of the characters in the store associated with the return circuit.

Fig.2 shows the repetition cycle. For simplicity, it has been drawn with the transmission delay equal to the time of transmission of one character. Characters A, B, C, D, . . . are shown transmitted from terminal 1 to terminal 2, while characters P, Q, R, S, . . . are transmitted in the reverse direction. The diagram shows the sequence resulting from the character C, transmitted from terminal 1, being falsified in transmission, and received at terminal 2, after the propagation delay, where it is detected as an error. At terminal 2 the return circuit is interrupted at the first opportunity to allow the transmission of the RQ signal and a repetition of the four previously transmitted characters from the store (P, Q, R and S), while the output printer is stopped for the duration of five characters. At terminal 1, receipt of the RQ signal, after the propagation

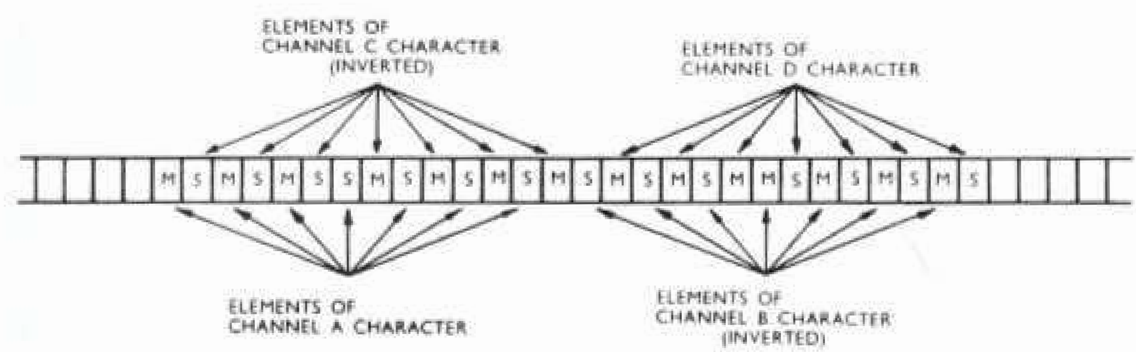
delay, stops the output printer for the duration of five characters, and interrupts normal transmission to send the RQ signal together with a repetition of the characters in store (C, D, E and F). At terminal 2, receipt of the RQ signal during a repetition cycle is arranged not to initiate another repetition cycle, and normal traffic is resumed.

5.1 ERROR INDICATION

If no return circuit is available, when an error is detected, the 5 space combination (signal No. 32 of the international telegraph alphabet, which is not generally used on the teleprinter), can be transmitted on the 5-unit start-stop output wire to cause a special error symbol to be printed on a suitably modified printer.



2-channel multiplexing—elements of the aggregate signal (MMMSSSS transmitted on each channel)



4-channel multiplexing—elements of the aggregate signal (MMMSSSS transmitted on each channel)

Fig.3.

6 MULTIPLEXING TELEGRAPH CHANNELS

It is convenient to transmit two telegraph channels in time-division multiplex on 100 baud circuits, and four channels on 200 baud circuits. When a 7-element 3-mark code is used, the polarity of the elements of characters on certain channels is changed to permit channel recognition. The following preferred arrangements are recommended by the C.C.I.T:

(a) 2-channel systems:
Characters of channels A and B shall be transmitted consecutively (character interleaved). Channel A characters shall be transmitted normally, while the elements of channel B characters shall be inverted (i.e. mark replaces space, and vice versa).

(b) 4-channel systems:
Characters of channels A and B shall be transmitted consecutively. The elements of channel C characters shall be interleaved with those of channel A characters, and the elements of channel D characters shall be interleaved with those of channel B. Channels A and D shall be transmitted normally, while channels B and C shall be inverted. Fig.3 shows the arrangement. It can be seen that two 2-channel systems can readily be connected to form a 4-channel system by element interleaving of the two 2-channel aggregate signals, and deriving all timing operations from one of the equipments.

7 DESIGN TECHNIQUES

The first error correcting equipments to be introduced were electro-mechanical in design, using motor-driven segmented discs with brushes to provide distributor functions, and electro-mechanical relays for other circuit functions.

A design based wholly on an electronic solution is to be preferred on most grounds. Desirable features include small size, low power consumption and heat dissipation, and reasonable cost. Because of the complexity of the equipment, ease of testing and observing the condition (mark or space) of the signal elements in the various circuit stages is important. Since several hundred valve circuits (or the equivalent) are incorporated

in the terminal equipments, reliability is of even more than usual importance.

A number of approaches are possible,

(a) All thermionic valve circuits.
(b) All transistor circuits.
(c) Circuits using thermionic valves and cold-cathode valves.
(d) Circuits using thermionic valves and magnetic cores.
(e) Circuits using transistors and magnetic cores.

A design using all thermionic valve circuits, many of which are two valve binary circuits, together with neon lamps to indicate signal condition, is bulky and power-consuming, while the reliability is not of a high order.

In considering an all-transistor design, it should be borne in mind that since transistors are basically amplifying devices rather than on-off circuit elements, they must be used in pairs in binary circuits, and relatively complex indicating devices are required to show signal conditions. A great number of transistors would be required for the complete equipment, and it can be concluded that this arrangement is inferior to a design using a combination of transistors and magnetic cores. Considering the alternative combination of thermionic valves and magnetic cores, it is probable that this would be cheaper though more bulky.

Circuits using magnetic cores for this application are still in the experimental stage.

At the present time circuits using cold-cathode valves for dividers, distributors, storage and counting stages are an attractive alternative. The cold-cathode valve is basically an on-off device which, according to type, requires little or no standby power, provides a visual indication of its on-off condition, and is satisfactory for the low speed applications (up to about 10 kc/s) required in error-correcting equipment. Cold-cathode valves are cheaper than transistors, have better overload characteristics, and vary much less with temperature. They also have long life, especially as in most of the circuits they are struck for only a small percentage of the time, but are bigger than transistors (the smallest size is sub-miniature).

Circuits using cold-cathode valves are not familiar to a great many

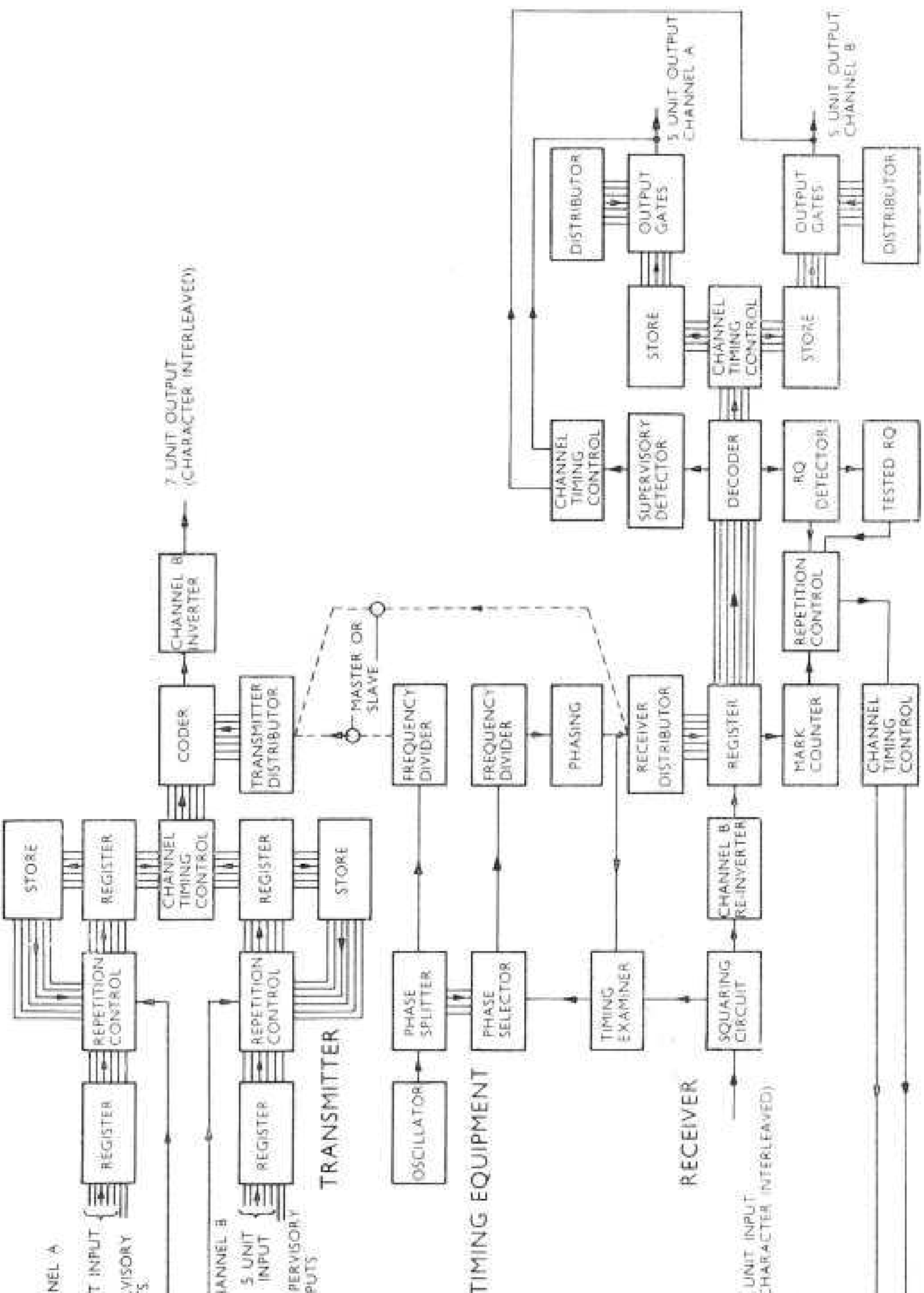


Fig.4. Simplified block diagram of two-channel time-division error correcting terminal equipment

engineers, and their merits for certain applications have tended to be overlooked. In the Appendix, details are given of some circuits used in error correcting equipment.

8 EQUIPMENT DESIGN

The design of an error correcting terminal equipment will now be considered. Fig.4 shows the simplified block diagram of a typical terminal meeting the C.C.I.T recommendations.

8.1 TRANSMITTER CIRCUIT

Referring to Fig.4, 5-unit characters from a perforated tape and tape reader, or similar device, are registered, when required, at the inputs of the channel units. As each character is transmitted over the system the tape reader is driven on to provide the next input character. The characters from the two input registers are normally fed to further registers and passed in turn, as directed by the channel timing control circuit, to the coder. At the same time, the transmitted characters are passed to channel stores. (It should be noted that the storage stage can, as an alternative, follow the coder and be at the 7-element stage.) Three characters are normally registered in each shifting store and are discarded in turn if a repetition is not required. To facilitate the introduction of supervisory signals the registers and stores operate on a 6-element basis. For characters from the tape the 6th element is always space, while for supervisory signals the 6th element is mark. In the coder the 5-unit character, or supervisory signal, is translated to give the appropriate 7-element permutation, and the output is converted, by means of a distributor, to a sequential aggregate signal, which is passed, via a circuit which inverts the elements of channel B characters, to the radio transmitter.

8.2 RECEIVER CIRCUITS

The output of the radio receiver is applied to a squaring circuit, and re-inverted for the channel B period; the elements of the incoming signal are examined at their nominal mid-instants and registered in the correct sequence by means of the receiver distributor. The 7-wire output of the register is applied to the decoder and the output characters are trans-

ferred in turn, under the control of the channel timing circuit, to the appropriate 5-unit channel store. (Registration in these character stores is required to permit the transition from simultaneous to start-stop conditions.) The 5-unit signal is read out of the store sequentially, via output gates, by a distributor operating at the required telegraph speeds. (Alternatives of 50 and 45·45 bauds may be required.) Start and stop elements are added and the composite output is passed to the receiving printer. If a supervisory signal is detected by the decoder the corresponding condition (continuous mark or continuous space) is applied to the appropriate output printer wire.

8.3 AUTOMATIC REPETITION CIRCUITS

As the incoming signal is registered, the number of marks in each character is counted. If the count is incorrect, or if the decoder detects the RQ signal, a repetition cycle is initiated on the appropriate channel. In this period (normally four characters) output from the channel store is inhibited, and continuous mark polarity is applied to the channel output line to hold the printer. In the transmitter the repetition control circuit of the channel, on which the error or RQ signal was detected, stops the tape reader drive for the duration of the repetition cycle, and, after allowing the character already in the register to be cleared, sets up a 6-element permutation in the register, which is translated in the coder to the 7-unit RQ signal. After the clearance of this signal the repetition control circuit causes the characters in the store to be re-transmitted. As these characters are transmitted they are automatically stored again in case a further repetition cycle is required, one of the supervisory signals (the idle time signal corresponding to continuous mark) being stored in place of the RQ signal. At the end of the repetition cycle normal traffic is resumed. The repetition only interrupts traffic on the channel in which the error occurred, while normal traffic proceeds on the other channel.

8.4 TIMING CIRCUITS

The timing of the various stages in the equipment is derived from a stable frequency source such as a crystal oscillator. The transmitter and receiver channel and element distributors are driven from the oscillator via frequency divider stages. By choosing a suitable crystal frequency, and

permitting a choice of the scale of frequency division, the equipment can be arranged to operate at the various required aggregate speeds. The C.C.I.T recommends speeds of 171 3/7, 192 and 200 bauds for 4-channel circuits.

8.4.1 *Synchronizing*

To ensure synchronism between the transmitter and remote receiver, constant correction is applied to the timing of the receiver distributors. In the arrangement shown in Fig.4 the first stage of frequency division following the oscillator provides multi-phase outputs, and a timing examiner circuit compares the relative timing of the transitions of the incoming signal, with those of a signal derived from the output of the receiver frequency divider. If the transitions of the incoming signal are too early, the phase selector advances the phase of the drive to the receiver frequency divider. If they are too late, a retarded phase is selected. The incoming signal may be severely time-distorted, and to prevent unnecessary changes of phase an integrating device may be included so that the phase is shifted only after a tendency towards early or late transitions has been established. According to the order of frequency division, the distributor can be adjusted in this way in steps of the order of 1% of an element. If no traffic is being passed over the system it is desirable to maintain precise synchronism in this way by transmitting one of the idle or supervisory signals. To prevent undue loss of synchronism during periods when there may be no aggregate input to the receiver, the stability of the oscillator must be very high, of the order of ± 1 part per million.

Two terminal equipments are normally operated on a master-slave basis.

8.4.2 *Phasing*

An equipment should synchronize automatically on being switched on. It is then likely to be out of phase since there are 14 possible phase relationships between elements of a 2-channel system. When an equipment is out of phase there will not be a constant mark-space relationship and a repetition cycle will be initiated. After a specific period during which no RQ signal has been detected, adjustment of phase will take

place automatically by changing the receiver distributor phase by one element per repetition cycle. This change of phase will continue until the RQ combination is detected on both channels.

8.5 TESTED RQ CIRCUIT

A 'tested RQ' facility to provide some measure of protection against undetectable errors may be considered desirable. During a repetition cycle one of the incoming characters should be the RQ signal. If this is not detected during a repetition cycle, it can be assumed that the transmission conditions are bad and that the repetition may contain undetectable errors. Another repetition cycle is then initiated.

9 MECHANICAL DESIGN

As mentioned before, the terminal equipment includes some hundreds of valve stages or equivalent circuit elements. The mechanical design of the equipment should, therefore, be arranged to permit easy and rapid servicing and maintenance. Adequate test points should be readily accessible and the signal condition in the various circuits should be indicated at a glance.

Fig.5 shows a typical unit (in this case, the 7-element receiver register) of an error correcting multiplex equipment using cold-cathode valves. The unit is one of a number of mechanically identical plug-in units, and employs an etched wiring board. A high packing efficiency is achieved to minimize the overall size of the equipment.

10 ANCILLARY EQUIPMENT

Various special input devices are required for use in conjunction with the basic error correcting equipment to permit integration with other parts of the telegraph system (see Fig.6).

10.1 START-STOP TO SIMULTANEOUS CONVERTER

A 5-wire simultaneous input is generally preferred in the basic design of an error correcting equipment rather than the alternative of a sequential start-stop input on one wire; a start-stop to simultaneous converter can be added when required.

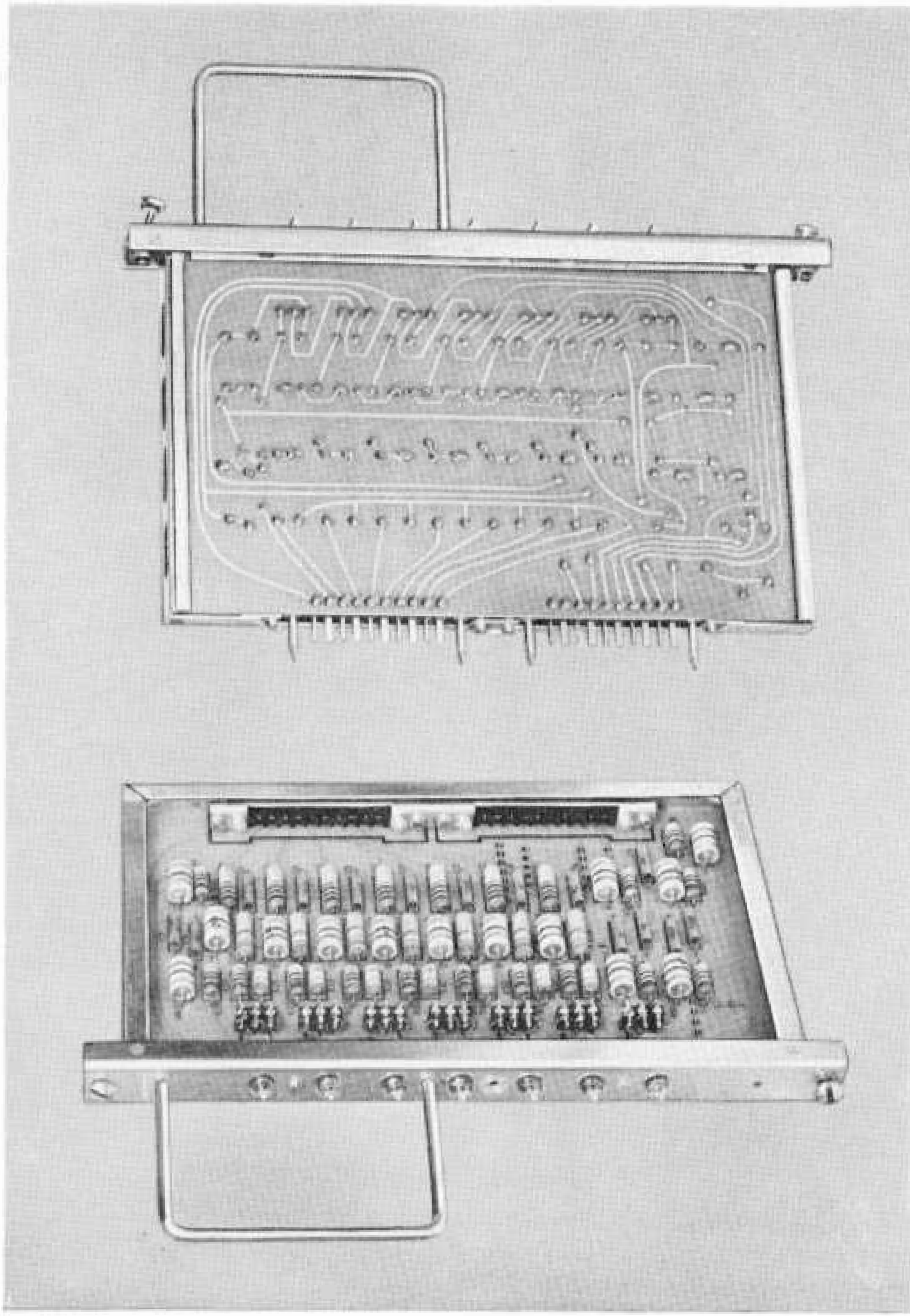


Fig.5. Typical unit of error-correcting multiplex equipment

The error correcting equipment then requires two additional input wires to permit the introduction of the supervisory signals which are required for switched working (such as Telex) or to indicate the 'no traffic' condition.

The converter includes:

(a) Means for driving the remote start-stop transmitter under the control of pulses from the error correcting equipment.

(b) A distributor and associated circuit to register the incoming sequential signal, and convert it to a simultaneous condition.

(c) A store (necessitated by the loop delay of the circuit) to which the information in the register is transferred prior to its presentation to the error correcting equipment. (The next character to be transmitted over the system is held in the store during a repetition cycle and while another sequential input character is being registered.)

(d) Provision for detecting the continuous mark and continuous space supervisory signals.

10.2 TAPE READER

The 5-wire inputs to the transmitter channel panels of the error correcting equipment may be obtained from a tape reader, which can be stepped when required by pulses from the equipment. The tape reader is provided with finger contacts to indicate the presence of the holes in perforated tape, and other contacts to indicate 'tight tape' and 'no tape'.

10.3 TELEX ADAPTOR

An adaptor is required to permit the input signals to the error correcting equipment to be derived from a receiver-reperforator-transmitter (providing tape storage) or similar device, fed from the Telex network. Means must be provided for transmitting the Telex idling conditions, and indicating the number of characters correctly transmitted (i.e. excluding repetitions) to enable the call to be charged.

10.4 CHANNEL SUB-DIVIDER

This unit enables a number of circuits to use the same channel on a time-sharing basis. Successive characters transmitted over the system are taken in turn from a number of separate remote start-stop transmitters, while

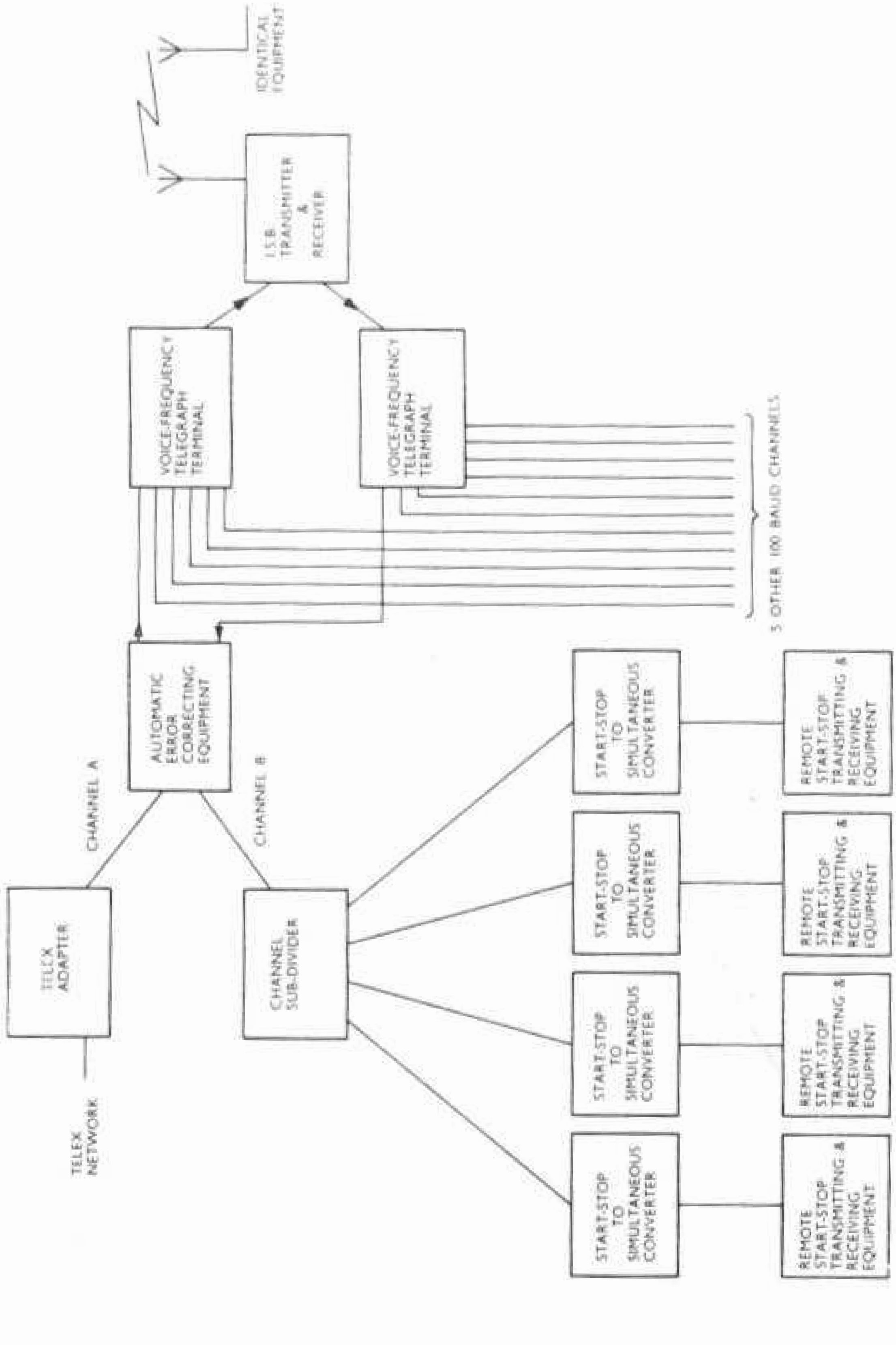
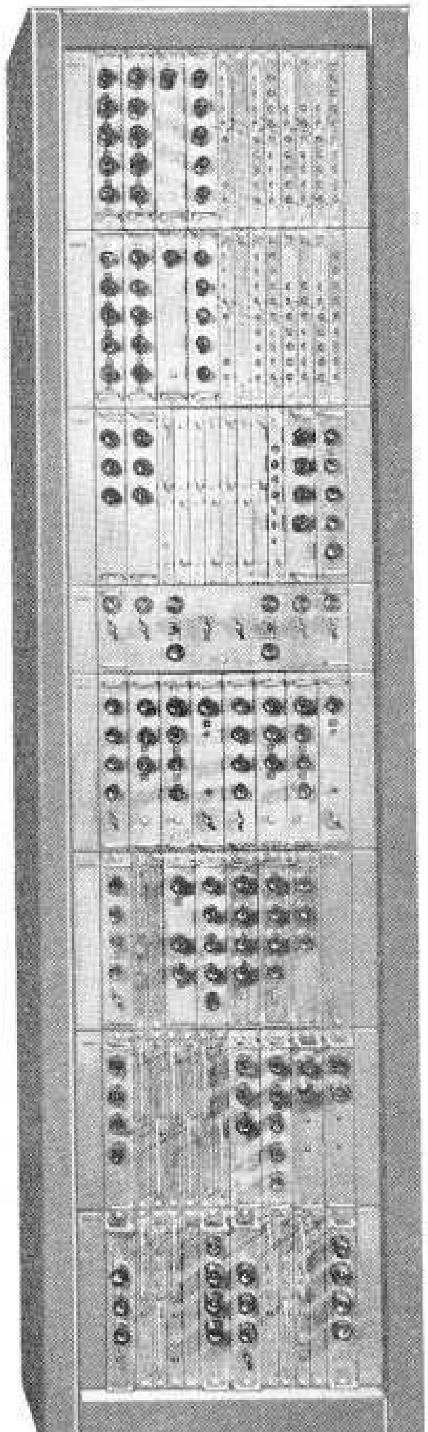


Fig.6. Block diagram of a telegraph system



TRANSMITTER PANEL CHANNEL 'A'

TRANSMITTER PANEL CHANNEL 'B'

CODER AND OUTPUT PANEL

CONTROL PANEL

TRANSMITTER AND RECEIVER DISTRIBUTOR PANEL

RECEIVER INPUT PANEL

DECODER PANEL

RECEIVER OUTPUT PANEL CHANNELS 'A' AND 'B'

Typical automatic error-correcting multiplex telegraph equipment for two 50-baud 5-unit teleprinter circuits. (Power, oscillator, frequency division and correction circuits are housed at back of equipment.)

received characters are transmitted in turn to the several associated start-stop receivers. A start-stop to simultaneous converter (see 10.1) is used in conjunction with each remote start-stop equipment. The output to the sub-channel start-stop receiver is transmitted at normal telegraph speed and continuous mark polarity is transmitted during the intervals between successive characters. To avoid crossed sub-channels, and permit automatic sub-channel phasing, one sub-channel is inverted. (This overrides the existing channel B and C inversion.)

11 CONCLUSION

The 7-unit 3-mark code, in widespread use on radio circuits, permits the use of error correction techniques. The early electromechanical equipments were not ideal, and recent experimental work in the UK and elsewhere showed that fully electronic solutions are now possible.

Equipment based on the van Duuren system has now been designed using cold cathode triodes and printed wiring. This offers, at present, the best arrangement for simple, reliable equipment which can be maintained in service without undue difficulty.

Appendix

COLD-CATHODE VALVE CIRCUITS FOR ERROR-CORRECTING EQUIPMENT

THE CIRCUITS to be described here use three electrode cold-cathode trigger valves, sometimes known as cold-cathode triodes; the three electrodes are the anode, cathode and trigger.

Vb = HT supply voltage
Vam = anode-cathode maintaining voltage
Vas = anode-cathode striking voltage
Vts = trigger-cathode striking voltage

$$Vam < Vb < Vas$$

Fig.7 shows the basic pulse-plus-bias trigger valve circuit. The bias applied to the trigger and the amplitude of the input pulse are chosen so that each is less than Vts but their sum exceeds Vts. With the valve initially non-conducting the output terminal is at earth potential. On coincidence of the input pulse and bias potential the valve strikes between trigger and cathode and, as a result, between anode and cathode. The anode-cathode voltage then falls to Vam, and the output potential rises. Once the valve is struck, removal of the trigger potential has no effect, and the tube can only be extinguished by reducing the anode-cathode potential to a value less than Vam.

1 SELF-EXTINGUISHING COUNTER CIRCUITS

A counter circuit using cold-cathode trigger valves is shown in Fig.8. A train of drive pulses of amplitude insufficient to strike an

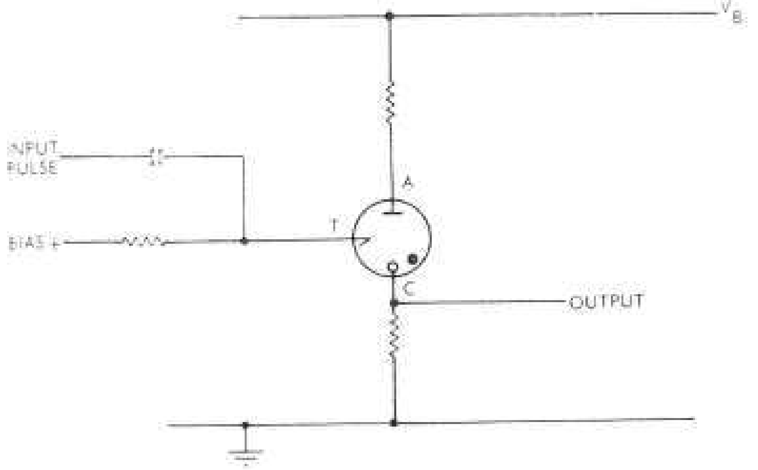


Fig.7. Pulse-plus-bias trigger valve circuit

unprimed valve is applied via capacitors to all the triggers. On connecting priming bias to V_1, the next drive pulse strikes V_1. The voltage of the common anode line falls instantaneously to a value Vam, and capacitor C_1 charges to a value

$$\frac{(Vb-Vam)R_1}{R+R_1}$$

thus priming V_2 ready for the next pulse. The succeeding pulse strikes V_2, and the voltage of the common anode line falls instantaneously to Vam. (As the cathode of V_2 momentarily remains at zero potential due to the presence of C_2.) The cathode potential of V_1 is initially held at its positive value, reducing the voltage across V_1 below the maintaining voltage, thus extinguishing it. The process is repeated for subsequent drive pulses, conduction shifting one valve along the chain each time.

The circuit can be connected as a ring instead of a chain by obtaining the priming bias for V_1 from the cathode of V_n. The self-extinguishing ring counter can be used for many applications.

1.1 *Distributor*

Fig.9 (a) shows a ring counter used as a distributor, while Fig.9 (b) shows the input and output waveforms.

1.2 *Frequency Divider*

The circuit shown in Fig.9 also forms the basis of frequency division networks, when only a single output is used.

1.3 *Phase Splitter*

The outputs at the cathodes of the several valves in a ring counter are at the same frequency but in different phase relationships. If the pulse drive to a subsequent stage is derived from the output of a ring counter, the phase can be advanced and retarded by selecting alternative outputs. Fig.10 shows cold-cathode valve circuits used to provide the timing requirements of the equipment shown in Fig.4. The relative phase of the transmitter and receiver element distributors may be adjusted according to which of the phase selector gates is opened.

1.4 *Both-way Counter*

Fig.11 shows the circuit of a both-way counter. Drive pulses on the 'A' line step the counter forward, while pulses on the 'B' line step it backwards. Such a circuit is used in, for example, the timing examiner. Pulses due to early transitions of the incoming signal drive the counter in one direction, while late pulses drive it in the opposite direction. When the valves at the ends of the chain are struck they provide drive pulses which cause the phase selector to advance or retard the phase of the drive to the receiver frequency divider, and operate a circuit which returns the conducting stage to the centre of the chain.

2 CIRCUITS WITH EXTERNAL EXTINGUISHING

A chain of cold-cathode trigger tubes may be extinguished by a pulsed HT supply (obtained, for example, from a cathode follower valve).

2.1 *Register with Sequential Input*

Fig.12 shows a register suitable for use as the receiving register of an error correcting equipment. At the commencement of the registering period of a new character, a negative character pulse applied to the grid of

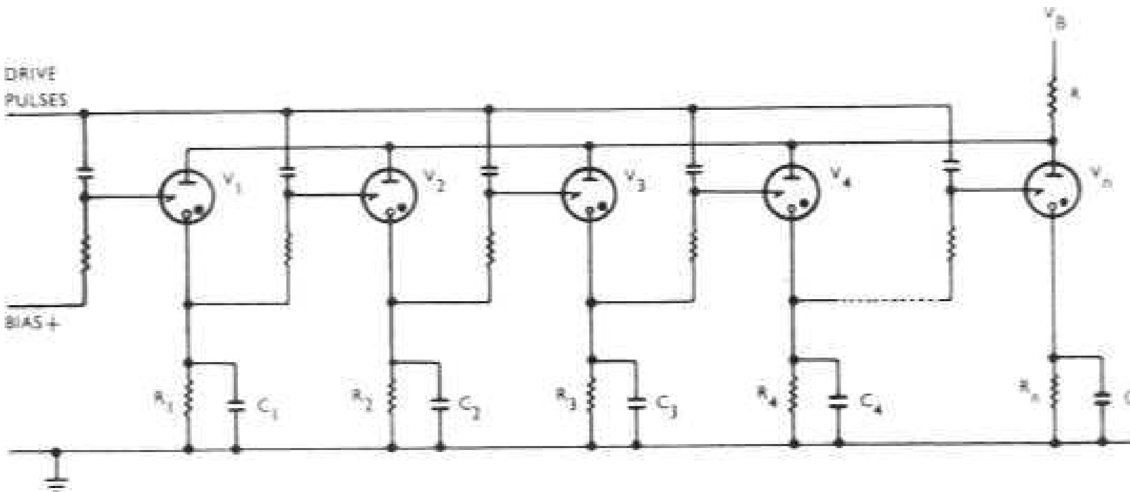
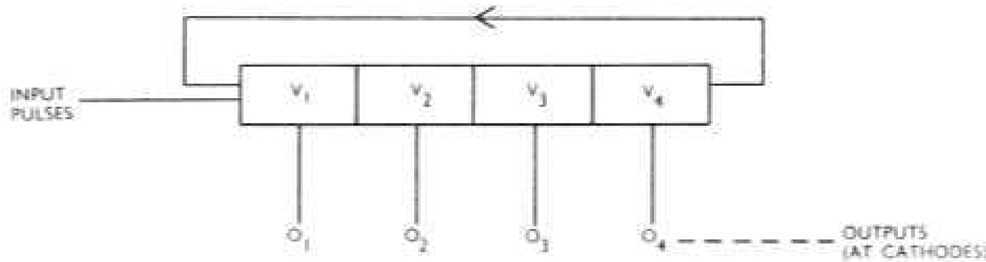
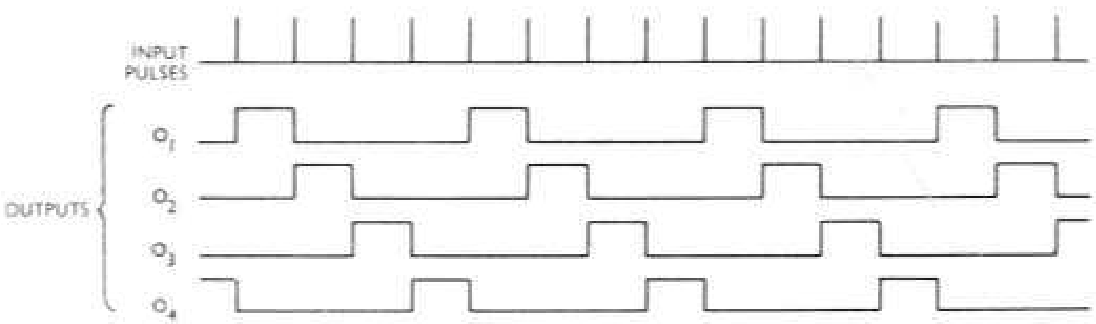


Fig.8. Counter-circuit using cold-cathode trigger valves



(a) Ring counter distributor



(b) Waveforms in the circuit
(a single output performs as a frequency divider)

Fig.9.

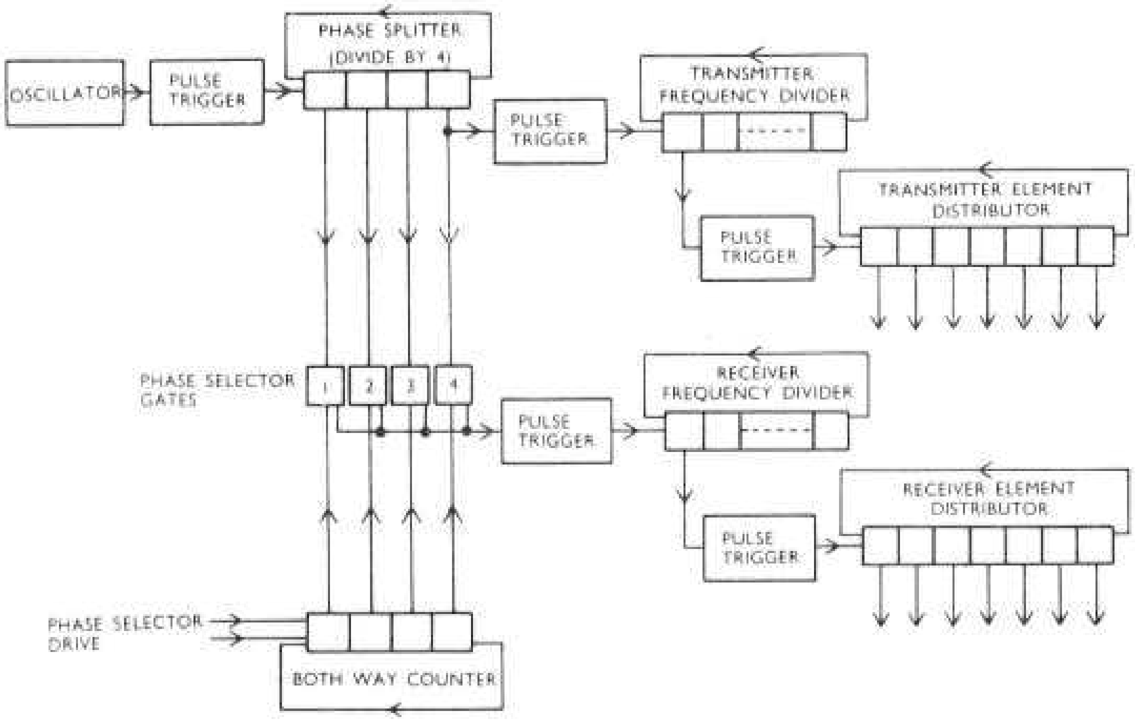


Fig.10. Timing equipment of a typical error correcting terminal – block diagram

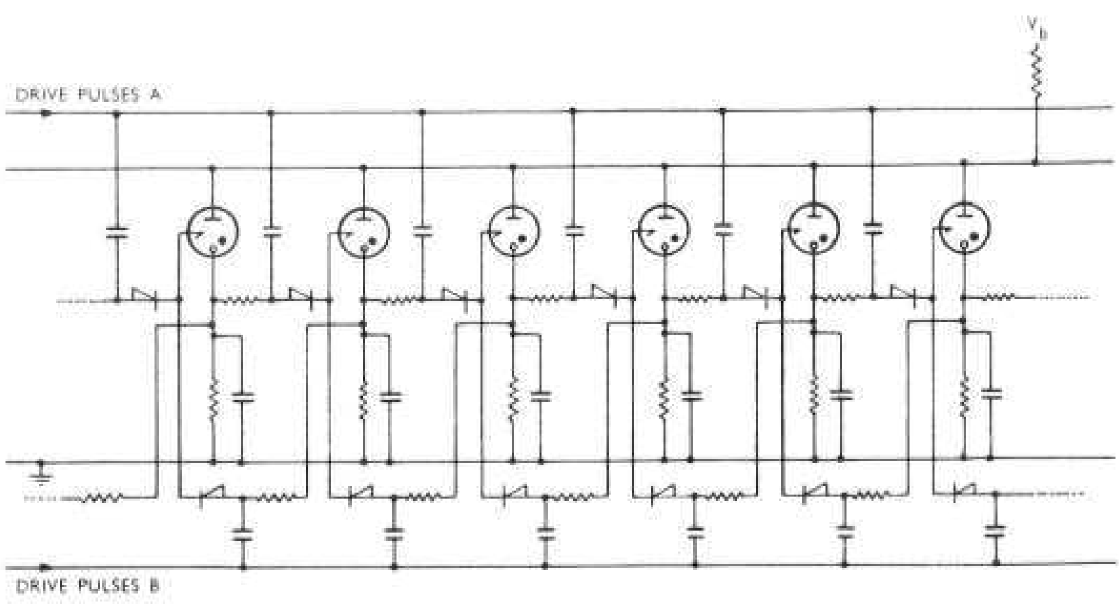


Fig.11. Both-way counter using cold cathode valves

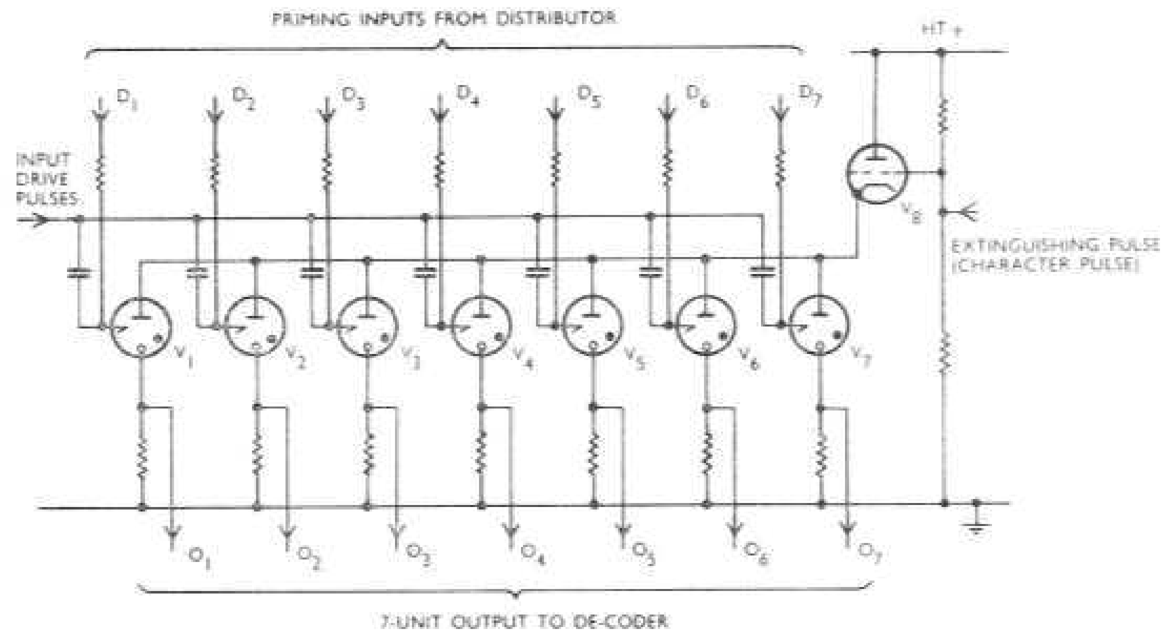


Fig. 12. Register using cold-cathode trigger valves

valve V_8 extinguishes all valves and clears the register. Input drive pulses, corresponding to marks in the sequential 7-element receiver input, are applied to all triggers. Priming voltage is applied to the triggers in turn from a distributor. In this way the appriopriate valves strike on co-incidence of pulse and priming, and register the input character. The sequential input signal is thus converted to a parallel output; the outputs from the cathodes are fed to the decoder. The next character pulse again clears the register ready for the next character.

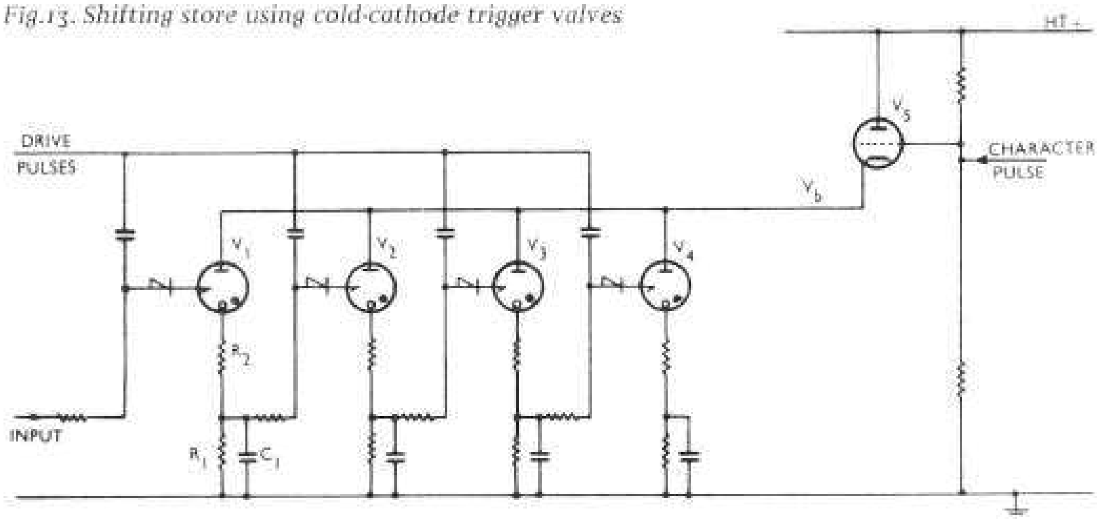
2.2 *Shifting Store*

Fig.13 shows a circuit which can be used for storing the conditions of a specific code element of a number of successive characters. Six such circuits would be used to store six-element characters; the drive pulses and pulsed HT supply would be common to all the element stores. A negative character pulse applied to the grid of V_5 lowers the HT momentarily. Simultaneously with the re-application of HT a drive pulse is applied to all the triggers. V_1 then strikes if the input (priming) voltage is positive, corresponding to a mark to be registered (the input terminal is at earth potential on space) and capacitor C_1 charges to a value

$$\frac{(Vb-Vam)R_1}{R_1+R_2}$$

At the next character pulse V_1 extinguishes but the charge remains on capacitor C_1 priming V_2 which strikes on the re-application of HT due to the co-incident drive pulse. Meanwhile, V_1 strikes or not according to whether the next element to be registered is mark or space. If V_1 is non-conducting (representing a space in the register) capacitor C_1 is at earth potential, V_2 is not primed and will not strike when the character pulse and drive pulse is applied. It is seen that at each character pulse an element of the new character is registered on V_1 and the condition of each valve is transferred to the next in order. Each conducting valve in the chain represents a mark stored.

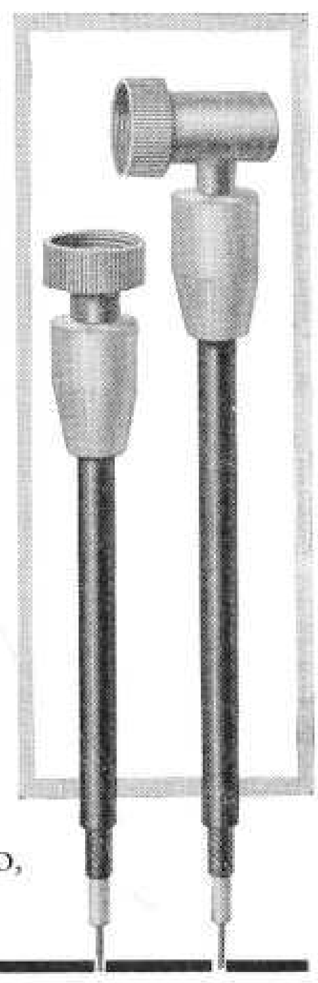
Fig.13. Shifting store using cold-cathode trigger valves

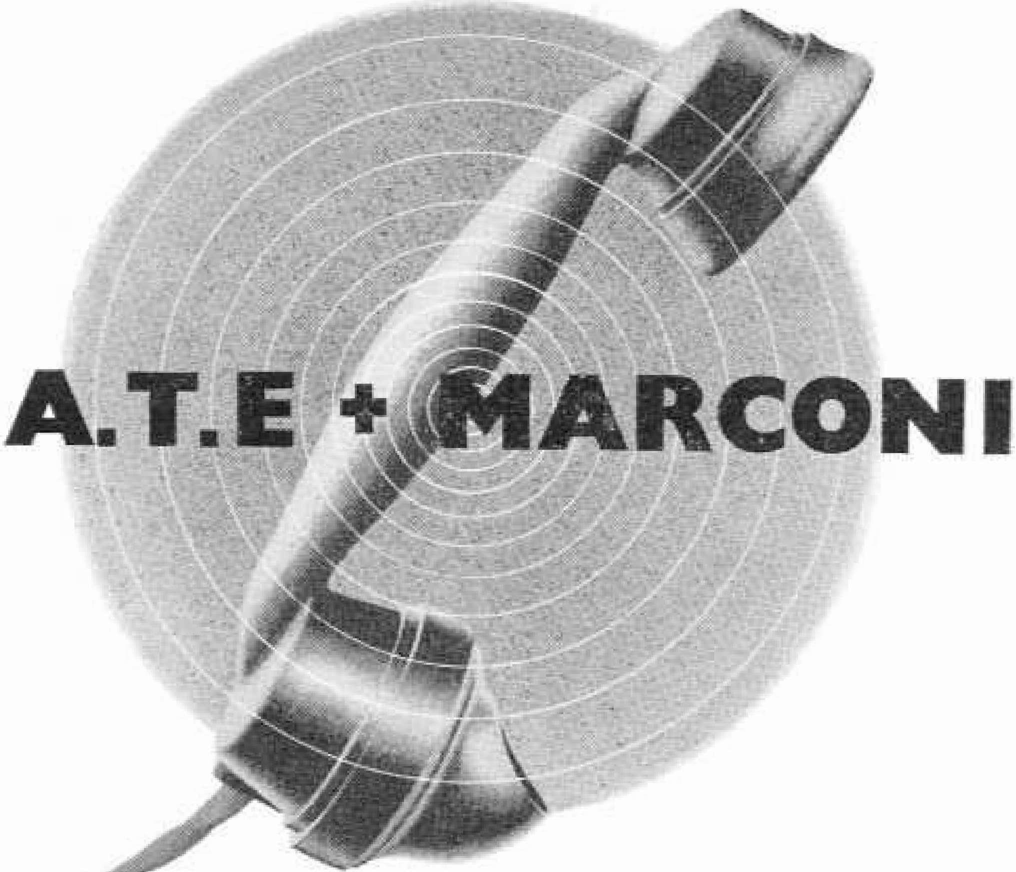


3 MARGIN CHECKS ON COLD-CATHODE VALVE CIRCUITS

A routine test which can be applied to the cold-cathode circuits of the equipment during no-traffic periods is the raising and lowering of the regulated supply voltages until a circuit fails to operate correctly. If the failure occurs for a relatively small change of supply voltage (e.g. less than 5%) it can be concluded that the stage is tending to become faulty and requires detailed checking. Thus faults in service can be minimized.

P. R. KELLER, born in 1924, in Harwich, graduated at King's College, London University, in 1944, after which he joined Marconi's Wireless Telegraph Co. In 1945 he was appointed to the Design and Development Division for work on Radar and Marine Communication equipment. Later he specialized in VHF equipment, and from 1950 was chief of the Established Designs Section, VHF Development Group, responsible for the planning and development of VHF systems and the design of associated special equipment. In 1956 he took charge of a new section formed to develop error-correcting telegraph equipment. For some years he lectured in the Engineering Department of the Mid-Essex Technical College. He is the author of *VHF Radio Manual*.

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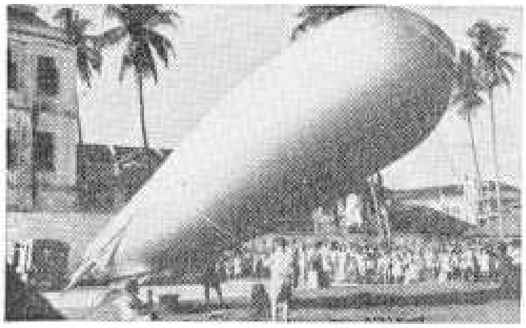
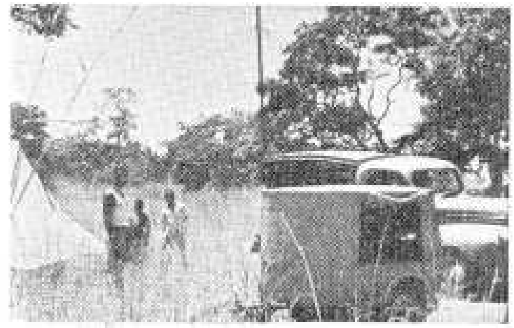
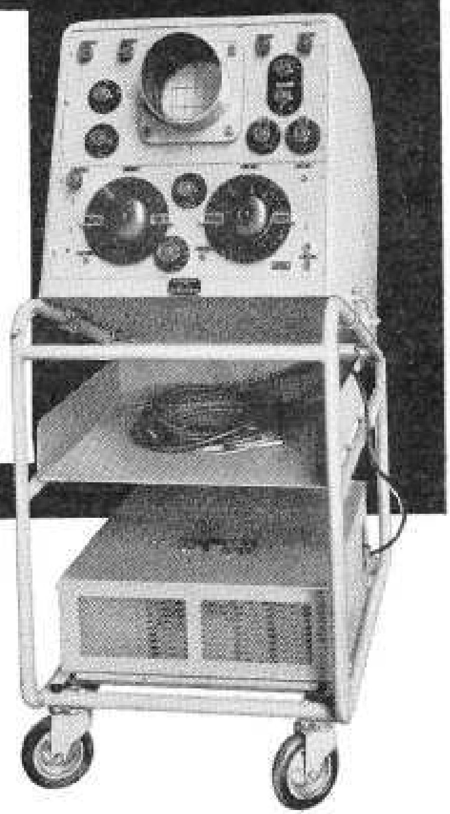




FOR CHECKING S.S.B. QUALITY

H.F. SPECTRUM ANALYSER

Type OA 1094



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